

## Database Development and Recognition of Handwritten Devanagari Legal Amount Words

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**Abstract**— A dataset containing 26,720 handwritten legal amount words written in Hindi and Marathi languages (Devanagari script) is presented in this paper along with a training-free technique to recognize such handwritten legal amounts present on Indian bank cheques. The recognition of handwritten legal amount words in Hindi and Marathi languages is a challenging because of the similar size and shape of many words in the lexicon. Moreover, many words have same suffixes or prefixes. The recognition technique proposed is a combination of two approaches. The first approach is based on gradient, structural and cavity (GSC) features along with a binary vector matching (BVM) technique. The second approach is based on vertical projection profile (VPP) feature and dynamic time warping (DTW). A number of highly matched words in both the approaches are considered for the recognition step in the combined approach based on a ranking scheme. Syntactical knowledge related to the languages is also used to achieve higher reliability. To the best of our knowledge, this is the first work of its kind in recognizing handwritten legal amounts written in Hindi and Marathi. Researchers interested in the dataset can contact the authors to get through a shared link.

**Keywords**- handwritten database; Devanagari script; legal amount recognition; handwriting recognition; Hindi and Marathi languages; bank cheque processing.

### I. INTRODUCTION

In India, around 300 million people use Devanagari script for writing languages like Hindi, Marathi, Sindhi, Nepali, Sanskrit, and Konkani, where Hindi is the national language of the country [1]. Hindi and Marathi are the most popular languages written in Devanagari script. As the national language, Hindi is accepted all over India and is used for documentation especially in the Indian states of Bihar, Chhattisgarh, Haryana, Himachal Pradesh, Jharkhand, Madhya Pradesh, New Delhi, Rajasthan, Uttar Pradesh and Uttarakhand. Marathi language is the official language of the Indian state of Maharashtra, which is one of the biggest states in the country.

To fill-up various paper documents like bank cheques, envelopes, application forms, railway reservation forms, answer sheets etc. people use Devanagari script. The script is written from left to right and has 13 vowels, 34 consonants and 14 modifiers. More characteristics of Devanagari script can be seen in [1]. Unlike Latin script, Devanagari has only one style of writing. There is no concept of cursive style in writing Devanagari script. Normally, to write a word, the constituent characters are written from left to right and then joined by a header-line called 'shirorekha' as shown in Figure. 1.

Legal amount, courtesy amount, date, payee details and signature are the fields to be filled by an account holder on a

bank cheque as shown in Figures 2 and 3. The value of a cheque is written in two ways in two areas. The first area (legal) contains the amount written in words and the second area (courtesy) contains the amount written in numerals. It is considered that the amount recognition has to rely on both courtesy and legal amount recognition. A state of the art survey on cheque recognition techniques can be found in [17]. This paper mainly deals with the recognition of handwritten legal amounts. Two types of approaches are mainly used for handwritten word recognition: analytical (local) and global (holistic). In analytical approaches, each handwritten word of the legal amount is recognized by recognizing its constituent characters. For the same, a word is divided (segmented) into components like characters or graphemes (part of characters) first. In global (holistic) approaches, the entire word is considered as a single unit (pattern) and recognition is done without any type of segmentation. Various techniques for the recognition of handwritten words can be found in the surveys carried out in [9], [10] and [11]. A survey of character level segmentation of handwritten words is done in [12].

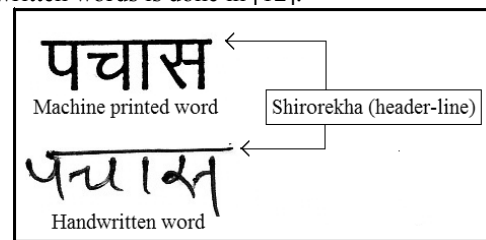


Figure 1. Machine printed and handwritten samples of a Hindi word (meaning 'fifty').

Although there are many works reported on non-Indian Bank cheque recognition [8, 13-16], to the best of our knowledge there is no work reported on bank cheques written in Indian languages. Only a few works are reported in the literature towards handwritten Devanagari words. For recognizing handwritten city names, which are distinct in their size and shape, Shaw et al. [2, 3] used a segmentation-based approach and a segmentation-free approach. In the segmentation-based approach [2], a word image is segmented into pseudo-characters and Hidden Markov models (HMM) are used to recognize them. In the segmentation free approach [3], continuous density-HMMs are used to recognize handwritten Devanagari words. An HMM is constructed for each Devanagari word. The states of the HMMs are determined automatically based on a database of handwritten city names. In [4], Shaw and Parui used a global approach that extracts global features from handwritten Devanagari words. A two-stage recognition scheme is used for the recognition purpose where the first

stage of recognition is based on an HMM classifier and the second stage is based on the Bayes discriminant function.

For the offline recognition of handwritten legal amounts in Marathi and Hindi languages, a technique that is a combination of two approaches in a single writer environment is presented in this paper. An individual can use 106 words in Hindi Language and 114 words in Marathi language for writing a valid legal amount, whereas in English there are only 30 to 36 words depending on the currency. It is assumed here that these word samples can be collected from an individual while opening an account with the bank. We have developed handwritten word image databases for Hindi and Marathi languages (Devanagari script) for the present study as there was no such database was available. We have designed special kinds of forms to collect the handwritten samples from the writers. The form contains different boxes in which a writer has to write all the possible words in the lexicon in a specified order. Most of the writers were from the age group 18 to 22. There was no restriction imposed on the writer regarding the style and speed of writing. These handwritten forms were then scanned at 300 dpi resolution to get the gray-scale images of the forms. The images were then skew corrected using radon transform. The words were then extracted using the location information as the words are written in ascending order of their value. Figure 4 and Figure 5 show these words being used for writing legal amounts in Marathi and Hindi languages collected from two individuals. The value of each word is shown on its right side. Handwritten words similar in size or shape are grouped together to illustrate the complexity in recognition, as many of the words in a group have same suffixes. To illustrate the type of cheques being

एक (1)	दोन (2)	तीन (3)	चार (4)	पाच (5)	सहा (6)	सात (7)	आठ (8)	नऊ (9)	दहा (10)
बारा (12)	तेरा (13)	चौदा (14)	सोळा (16)	वीस (20)	तीस (30)	साठ (60)	सोयी (80)	एकसहस्र (100000)	
एकरो (100)	दोनरो (200)	तीनरो (300)	चाररो (400)	पाचरो (500)	सह्यारो (600)	सातरो (700)	आठरो (800)	नऊरो (900)	
अकरा (11)	उठारा (18)	सव्वारा (17)	पंधरा (15)	रांभार (100)	हजार (1000)	सत्तर (70)	नव्वद (90)	फक्त (Only)	
एकवीस (21)	बावीस (22)	तेवीस (23)	चाळीस (40)	चौवीस (24)	पंचवीस (25)	सव्वीस (26)	सत्तावीस (27)	अठ्ठावीस (28)	
एकव्याणव (91)	दुव्याणव (92)	त्र्याणव (93)	चौ-द्याणव (94)	पंच्याणव (95)	शहाणव (96)	सत्याणव (97)	अठ्ठ्याणव (98)	नव्व्याणव (99)	
एकोणतीस (29)	एकोणवीस (19)	एकोणसहाठ (59)	एकोणसत्तर (69)	एकोणपंचशी (79)	एकोणनव्वद (89)	एकोणपन्नास (49)	एकोणचाळीस (39)		
पन्नास (50)	उक्यावण (51)	बावण (52)	त्रेपण (53)	चोपण (54)	दुपण (56)	पंचण (55)	सत्तावण (57)	अठ्ठावण (58)	
करोटी (1000000)	रुपये (Rupees)	एकशहस्र (61)	दुसशहस्र (62)	त्रेशहस्र (63)	चौशहस्र (64)	पासशहस्र (65)	सहाशहस्र (66)	सप्तशहस्र (67)	अठ्ठाशहस्र (68)
		शहातर (76)	बाहतर (72)	त्राहतर (73)	चौ-चाहतर (74)	पंच्याहतर (75)	सत्ताहतर (77)	अठ्ठ्याहतर (78)	नव्व्याहतर (71)
		द्वापंचशी (82)	त्रापंचशी (83)	चौ-पांचशी (84)	पंच्यापंचशी (85)	शहापंचशी (86)	सत्त्यापंचशी (87)	अठ्ठ्यापंचशी (88)	

Figure 4. Marathi words belonging to an individual (total 114) from the database

used, two handwritten cheques in Marathi and Hindi languages are also shown in Figures 2 and 3. The recognition technique proposed here is a combination of two approaches. The first approach is based on GSC features along with a BVM technique, whereas the second approach is based on VPP feature and DTW. The two subsequent sections of the paper discuss the recognition technique and the details of experimentation, whereas the last section concludes the paper.

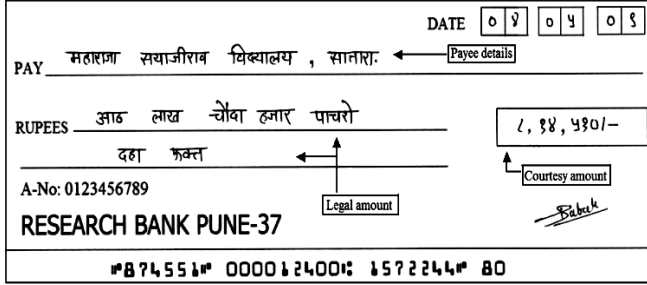


Figure 2. A cheque written in Marathi language

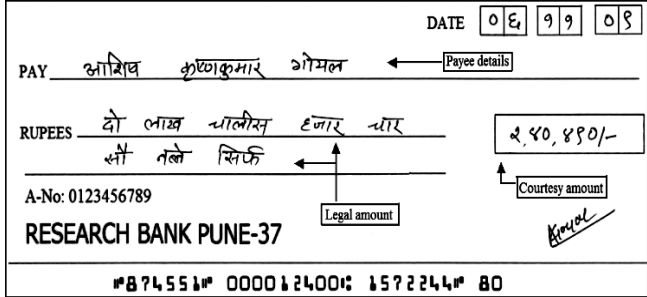


Figure 3. A cheque written in Hindi language

दो (2)	सौ (100)	नौ (9)	रु (Rs.)
एकार (1000)	लाख (100000)	करोरु (1000000)	सिफि (Only)
रुपये (Rupees)	ग्यारह (11)	बारह (12)	तेरह (13)
चौदह (14)	पंधह (15)	सोलह (16)	सत्रह (17)
अठारह (18)	उत्तीस (19)	इक्कीस (21)	बईस (22)
तेईस (23)	चौबीस (24)	पन्चीस (25)	एठ्ठवीस (26)
सोत्तीस (27)	अठ्ठाईस (28)	अत्तीस (29)	
एक (1)	दो (2)	तीस (3)	चार (4)
पाँच (5)	छह (6)	सात (7)	आठ (8)
दस (10)	ब्य (10)	बीस (20)	तीस (30)
आठ (60)	नबे (90)	तेईस (23)	चौबीस (24)
पन्चीस (25)	एठ्ठवीस (26)	सोत्तीस (27)	अठ्ठाईस (28)
अत्तीस (29)			
द्वय्यातबे (91)	बानबे (92)	तियतबे (93)	चौसातबे (94)
पंच्यातबे (95)	छियातबे (96)	सत्तातबे (97)	अठ्ठातबे (98)
द्वियातबे (99)			
द्व्यापंची (79)	त्रयापंची (80)	चौप्यापंची (81)	पंच्यापंची (82)
शहापंची (83)	सत्यापंची (84)	अठ्ठ्यापंची (85)	नव्व्यापंची (86)
अठ्ठहत्तर (69)	नव्वहत्तर (70)	इक्कीहत्तर (71)	बईहत्तर (72)
तेईहत्तर (73)	चौबईहत्तर (74)	पंचहत्तर (75)	छहहत्तर (76)
सातहत्तर (77)	आठहत्तर (78)	दसहत्तर (79)	सोलहहत्तर (80)
सत्रहहत्तर (81)	अठारहहत्तर (82)	अठ्ठाहत्तर (83)	अत्तीहत्तर (84)
अठ्ठाहत्तर (85)	अत्तीहत्तर (86)		
अठ्ठाहत्तर (87)	अत्तीहत्तर (88)		
अत्तीहत्तर (89)			
अठ्ठाहत्तर (39)	अत्तीहत्तर (40)	अत्तीहत्तर (41)	अत्तीहत्तर (42)
अत्तीहत्तर (43)	अत्तीहत्तर (44)	अत्तीहत्तर (45)	अत्तीहत्तर (46)
अत्तीहत्तर (47)	अत्तीहत्तर (48)		

Figure 5. Hindi words belonging to an individual (total 106) from the database.

## II. WORD RECOGNITION

As a valid legal amount text written in Hindi or Marathi language has a number of constituent words, the words have to be extracted first before being recognized. In order to extract words from a cheque image, a layout-based approach is employed. The area of interest is located with the help of guidelines present on the cheque. Guidelines are then removed using morphological operations as described in [8] and the stroke reconstruction is performed using structural elements in different directions. Handwritten words can be separated by observing the connected components and the distance between two consecutive connected components. This is based on the assumption that the intra word gaps are always smaller than the inter word gaps. Each extracted word is then recognized by comparing its features with that of the words in the database written by the same writer. The features, matching and the final word selection are described in the following subsections. An overview of the entire word recognition scheme can also be seen in Figure 6.

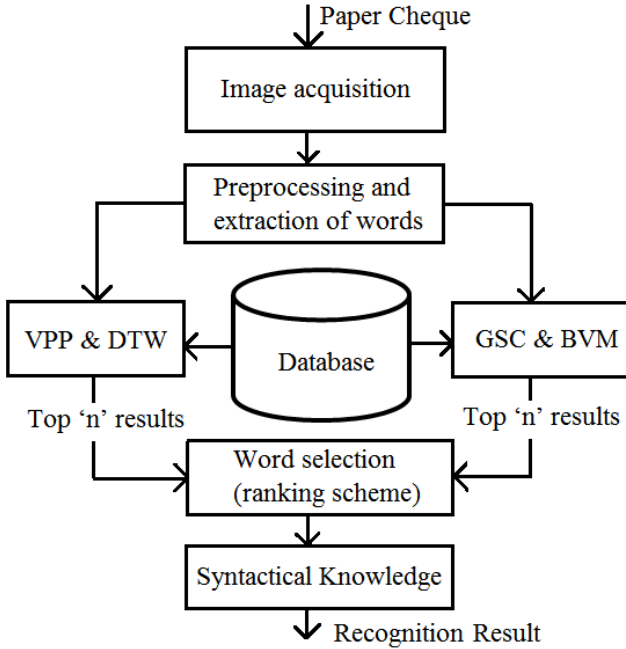


Figure 6. Overview of the proposed recognition scheme

### A. GSC Features and BVM

After skew and slant corrections, each binary handwritten word image is divided vertically into 4 segments such that every segment has same number of foreground pixels. Then the image is divided horizontally into 8-segments in the same way. This will result in 32 ( $4 \times 8$ ) image sub segments. For each sub segment, its corresponding gradient structural and cavity (GSC) features are extracted as described in [5]. The GSC features considered in this work are gradient values of the contours in seven major directions ( $22.5^\circ$ ,  $45^\circ$ ,  $67.5^\circ$ ,  $90^\circ$ ,  $112.5^\circ$ ,  $135^\circ$  and  $157.5^\circ$ ), presence of line segments in three different directions ( $90^\circ$ ,  $45^\circ$ , and  $135^\circ$ ), presence of four types of corners, presence of junction points, end points, loops, upper, lower, left and right cavities. A 21 (twenty

one) bit binary vector is created for the feature representation of each sub segment such that a bit is set to 1 if the corresponding feature is present. For gradient features, a threshold can be set for the number of contour pixels (with same gradient value) to set the corresponding bit value to 1. The binary vectors of the sub-segments are subsequently concatenated to form a 672 ( $32 \times 21$ ) bit binary vector for each handwritten word. The matching process of the word with those in the database collected from the same individual is carried out using the binary vector matching technique described in [6].

Let  $S_{ij}$  ( $i, j = 0$  or  $1$ ) be the number of bit level matches between  $i$  in the first pattern and  $j$  in the second pattern at the corresponding positions. The four possible values are  $S_{00}$ ,  $S_{01}$ ,  $S_{10}$  and  $S_{11}$ . Let  $X$  and  $Y$  be the feature vectors of two words to be compared, then the dissimilarity between them can be calculated using the following equation.

$$D(X, Y) = \frac{1}{2} - \left( \frac{S_{11}S_{00} - S_{10}S_{01}}{2\sqrt{(S_{10} + S_{11})(S_{01} + S_{00})(S_{11} + S_{01})(S_{00} + S_{10})}} \right) \quad (1)$$

### B. VPP and DTW

Vertical projection profile (VPP) features are considered here along with dynamic time warping (DTW) for matching handwritten Devanagari words. Same technique was earlier applied for spotting handwritten English words in [7]. After skew and slant corrections, the VPP feature vector is computed by summing the pixel values in each column of the binary image. If the foreground pixels of the image  $I$  with height  $h$  are indicated by 0's, the value of the projection vector at column  $j$  can be computed as follows.

$$VP(I, j) = \sum_{r=1}^h (1 - I(r, j)) \quad (2)$$

A rectangular grid is used for matching two vectors in DTW. Each point (node) in the grid is associated with a 'Cost', which is the difference between the values of the vectors at the corresponding row and column positions respectively. The feature vector  $R$  of the reference (stored) word of length  $L_r$  is aligned along the  $X$ -axis of the grid and the feature vector  $T$  of the test word of length  $L_t$  is aligned along the  $Y$ -axis respectively.

Let  $(x_k, y_k)$  represents a point (node) on a warping path at the instance ' $k$ ' of matching. A path starting from node  $(1, 1)$  and ending at node  $(x_k, y_k)$  has a cost  $D(x_k, y_k)$  associated with it. The problem of finding the optimal path can be reduced to finding a sequence of nodes  $(x_k, y_k)$ , which minimizes the accumulated cost for a complete path ending at node  $(T, R)$  as follows.

$$D^{Min}(x_k, y_k) = Min[D(x_{k-1}, y_{k-1})] + Cost(x_k, y_k) \quad (3)$$

The dissimilarity between the two feature vectors is equal to  $D^{Min}(T, R)$ . It has to be made sure that the path will not turn

back on itself. Both the  $(x_k$  and  $y_k)$  indices either stay same or increase. Both  $x_k$  and  $y_k$  can only increase by 1 on each step along the path. The path starts at (1, 1) and ends at  $(T, R)$ .

### C. Recognition

A legal amount word extracted from the cheque has to be matched with the words collected from the same individual using the two techniques mentioned above. A number ( $n$ ) of highly matched words from both the techniques are considered to finalize the recognition result. A ranking scheme is employed for the same as follows.

Let  $S_G = \{W_{G1}, W_{G2}, \dots, W_{Gn}\}$  be the set of highly matched words from GSC-BVM method and  $S_V = \{W_{V1}, W_{V2}, \dots, W_{Vn}\}$  be the set of highly matched words from VPP-DTW method. The intersection of these two sets gives the final set ( $S_F$ ) of words to be considered.

$$S_F = S_G \cap S_V \quad (4)$$

The rank ' $R$ ' associated with a word ' $w$ ' in  $S_F$  is calculated as :

$$R = Gi + Vj . \quad (5)$$

Where,  $Gi$  and  $Vj$  are the ranks of the same word in  $S_G$  and  $S_V$  respectively.

The word having the highest rank is selected from the final set as the recognition result. If two words share the highest rank, then their rank in  $S_G$  (i.e  $Gi$ ) is considered for the final selection. If  $S_F = \emptyset$ , then the test word has to be rejected to attain higher reliability.

### D. Syntactical Knowledge

After recognizing all the words on a cheque, the syntax of the entire legal amount has to be analyzed to reject the words appearing at wrong positions. The syntactical knowledge (SK) is always language dependent and can be implemented as a set of rules. Some of the common rules applicable to Indian bank cheques are listed below.

- The first word should not be a word equivalent to 'crore', 'lakh', 'thousand', 'hundred', 'only' etc.
- The word equivalent to 'only' should appear only at the end of the amount.
- A word equivalent to 'crore' or 'lakh' or 'thousand' or 'hundred' or 'only' or 'rupees' should appear only once in the entire legal amount.
- Two consecutive words shall not belong to the group of the words equivalent to 'crore', 'lakh', 'thousand', 'hundred' etc.

## III. EXPERIMENTATION

The dataset has been grouped into three sub-datasets namely DB1, DB2 and DB3. DB1 contains data collected from 90 individuals in Marathi language where each individual contributed 114 word templates and a handwritten cheque. Thus DB1 has 10,260(114×90) handwritten words and 90 handwritten cheques in Marathi language. DB2 also has data in Marathi language, collected from 70 individuals with comparatively poor handwriting. DB2 has 7,980(114×70) handwritten words and 70 handwritten cheques. DB3 contains data in Hindi language collected from 80 individuals. Each individual contributed 106 word templates and a handwritten cheque. Thus DB3 has 8,480(106×80) handwritten words and 80 handwritten cheques in Hindi language. The three sub-datasets collectively have 26,720 handwritten Devanagari words and 240 handwritten cheques.

The word level correctness, error, rejection and reliability of the different experimental setups conducted are given in tables I, II and III. Table I depicts the individual performance details of GSC-BVM and VPP-DTW methods. It is clear from Table I that the GSC-BVM method outperforms the VPP-DTW on all the three datasets. It is also evident from the table that the syntactical knowledge (SK) can increase the reliability of the system by 5% to15%. Table II shows the performance details of the combined approach with different values of ' $n$ '. Table III shows the impact of syntactical knowledge (SK) on the combined technique by improving the reliability by 1 to 6%.

TABLE I. INDIVIDUAL PERFORMANCE DETAILS OF THE METHODS WITH AND WITHOUT SYNTACTICAL KNOWLEDGE

Attribute	Database	Word Level Results			
		Without SK		With SK	
		GSC & BVM	VPP & DTW	GSC & BVM	VPP & DTW
Correctness (%)	DB1	80.65	76.69	78.08	71.56
	DB2	76.50	61.31	72.77	53.86
	DB3	79.45	65.23	72.68	55.07
Rejection (%)	DB1	0.00	0.00	8.15	14.91
	DB2	0.00	0.00	12.60	27.79
	DB3	0.00	0.00	14.67	29.34
Error (%)	DB1	19.34	23.31	13.75	13.51
	DB2	23.49	38.68	14.61	18.33
	DB3	20.54	34.76	12.64	15.57
Reliability (%)	DB1	80.65	76.69	85.02	84.10
	DB2	76.50	61.31	83.27	74.60
	DB3	79.45	65.23	85.18	77.95

## IV. CONCLUSIONS

In India, there is a vast scope for research related to handwritten Devanagari text processing as almost 300 million people use Devanagari script for writing. A database is developed containing 26,720 handwritten Hindi and Marathi legal amount words and is made available to the global research community. This database can be used for

benchmarking several segmentation and classification (recognition) techniques. To the best of our knowledge, it is the first database of its type (legal amount words). A combined approach is discussed in the paper to recognize legal amount words in a single writer environment. It is also demonstrated that the combined approach performs better than the individual methods in terms of correctness and reliability. By analyzing the individual performance details through experimentations, it became evident that the performance of GSC-BVM technique is superior to that of VPP-DTW technique. Reliability is important in automatic

cheque processing, as incorrect recognitions will result in huge financial losses. From the experimental results, it is clear that the use of syntactical knowledge improves the reliability of the recognition system. Also it is clear that more research is required to achieve a fully reliable system.

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TABLE II. WORD LEVEL PERFORMANCE DETAILS OF THE COMBINED APPROACH WITH DIFFERENT 'n' VALUES.

n	Correctness (%)			Error (%)			Rejection (%)			Reliability (%)		
	DB1	DB2	DB3	DB1	DB2	DB3	DB1	DB2	DB3	DB1	DB2	DB3
3	82.05	72.77	79.00	6.99	10.02	11.73	10.95	17.19	9.25	92.14	87.88	87.06
4	84.38	74.78	80.36	8.39	12.60	13.31	7.22	12.60	6.32	90.95	85.57	85.78
5	85.08	76.50	81.26	9.79	15.47	14.44	5.12	8.02	4.28	89.68	83.17	84.90
6	85.78	77.36	82.16	10.48	17.76	16.25	3.72	4.87	1.58	89.10	81.32	83.48
7	85.78	78.22	82.61	11.18	18.05	16.70	3.03	3.72	0.67	88.46	81.25	83.18
8	85.54	78.79	83.07	12.12	18.62	16.70	2.33	2.57	0.22	87.58	80.88	83.25

TABLE III. WORD LEVEL PERFORMANCE DETAILS OF THE COMBINED APPROACH (HAVING SK) WITH DIFFERENT 'n' VALUES

n	Correctness (%)			Error (%)			Rejection (%)			Reliability (%)		
	DB1	DB2	DB3	DB1	DB2	DB3	DB1	DB2	DB3	DB1	DB2	DB3
3	81.81	72.49	72.91	6.29	9.74	6.32	11.88	17.7	20.76	92.85	88.15	92.02
4	83.68	74.49	74.26	6.75	12.32	7.44	9.55	13.18	18.28	92.52	85.80	90.88
5	84.14	75.93	74.94	7.92	13.75	7.90	7.92	10.31	17.15	91.39	84.66	90.46
6	84.61	76.50	75.62	7.92	15.18	8.57	7.45	8.30	15.80	91.43	83.43	89.81
7	84.61	77.36	76.07	8.62	15.47	9.02	6.75	7.16	14.89	90.75	83.33	89.38
8	84.38	77.65	76.29	8.62	15.18	8.80	6.99	7.16	14.89	90.72	83.64	89.65

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