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Error Reduction in Promoted Confidence Factor of a Rule Using Improved Fuzzy Rule Promotion Technique

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Abstract: *A dynamic fuzzy rule promotion approach for the promotion of a confidence factor of a rule for every successful session in diagnosis of a disease in crops by using the specific rules, has already been proposed in literature. This technique has the limitation that an error in the initial estimation of weights reduces linearly after every session the rule is being used. In this paper an improved approach has been proposed using the square root of sum of squares of frequencies, which are spread around the mean true value to reduce the error around a mean value. A rule set for the diseases and their symptoms for the paddy plant has been provided to make comparison between the previous and the improved approach. It has been shown that the improved approach decreases the error in uncertainty of estimation of weight for rules after every successful session. It has also been proposed that the improved approach must be applied in agricultural information dissemination system.*

Keywords: *Improved rule promotion methodology, rule promotion methodology, Fuzzy Logic, confidence in rule, agricultural information System, weight factor, confidence factor.*

1. Introduction

Fuzzy Logic (FL) concerns precision: How important is it to be perfectly right when a rough response will do (Z a d e h [1], 1965)? A fuzzy set may have membership degrees between zero and one, as compared to the classical sets where each element must have either zero or one as a membership degree. The choice of FL presents an efficient and structural way of dealing with decisions involving parameters like ambiguity and inborn uncertainties of ecological processes and characteristics. A fuzzy expert system like an ordinary expert system uses FL methods. These systems use fuzzy data, rules and inference apart from those parameters found in the classical expert systems. In general, a fuzzy system consists of a knowledge base of a group of fuzzy if-then rules in the form of a database and an inference procedure, using these fuzzy rules and known facts to describe a result as described in [2], 2008. A fuzzy decision support system uses FL into its calculation process and/or knowledge representation scheme as described by K a n d e l [3]. Because of the robustness of these systems, when uncertain and imprecise data is used, it allows the accumulation of disparate input variables in a dependable and reproducible way and is applied in a wide range of agricultural, ecological and environmental issues [4, 5]. Linguistic rules with inexact terms in a group are defined as a fuzzy rule base. As mentioned by S i l e r and B u c k l e y in [6], depiction, processing and illustration of vague knowledge and uncertain data are the notable advantages of fuzzy theory. This theory can be applied to the development of knowledge based information systems.

2. Refrences review

A number of information systems have been developed in recent years using the application of FL in the area of agriculture and associated fields. Some of the systems include crop land suitability proposed by T. V. R e s h m i d e v i et al. [7], running of biogas reactor on energy crops by P. S c h e r e r et al. [8], managing water resources as mentioned by B. M a l e k m o h a m m a d i et al. [9], irrigation systems described by P. J a v a d i K i a et al. [10], yield behaviour using fuzzy cognitive maps proposed by E. I. P a p a g e o r g i o u et al. [11], assessment of soil conditions in agro-eco systems proposed by D i e g o O. F e r r a r o [12], planning of nutrient management for rice crops listedby D. K. S h a r m a and R. K. J a n a [13], minimizing grain losses especially at position of straw walker and upper sieve by automatic adjustment and control of a harvester as proposed by M a h m o u d O m i d et al. [14], studying land reallocation by T a y f u n C a y a n d and F a t i h I s c a n [15], sustainability of soil productivity by N e v c i h a n D u r u et al. [16], assessment of uncertainties in different management aspects of an environmental system by J. A. E. B. J a n s s e n et al. [17], T a n g H u i l i et al. [18], presented an agriculture disease diagnosis expert system using fuzzy reasoning and an Euclidean distance method which is used to calculate the comparability; efficient diagnosis results and reliabilities to fulfill the complexity of an agricultural disease problem. Mamdani Fuzzy Inference System

(MFIS) was used to classify the productive trees based on yield, fruit length and visual appearance, and to produce a tree total quality map mentioned by S. M. Mazloumzadeh et al. [19]. An exploratory study had been applied by Peng Xiaohong et al. [20], that builds a water-saving irrigation system using wireless sensor networks and fuzzy control technology. Localized weed prediction for control and management of weed infestation has been explored by Andrew Chou and Xinghuo Yu [21]. Most of the agricultural based information systems are having static behaviour pertaining to the use of knowledge base, reasoning and inference techniques [22]. To make a system, having dynamic behaviour, responding to these parameters, a novel technique of Fuzzy Rule Promotion (FRP) has been prescribed by Savita Kohle et al. [23].

3. Material and methods

FRP technique, provided by Savita Kohle et al. [23], has been defined for disease diagnosis in crops which uses the concept that every session used for firing a rule of a defined activity will enhance/reduce the confidence of a rule in a future session. The confidence factor is a quantitative value that defines the likelihood of the answer accurately identifying the desired activity. In this approach a weight/confidence factor of a rule is promoted/demoted according to its use during a successful/failure session for inferencing the final result for diagnosis of a disease in crops. In L. Jain et al. [24] have mentioned that the error in estimation of the true value of weight/confidence factor (cf) of a rule varies the error in the promoted confidence factor at a linear rate. It may be due to the reason that the error may be due to the variation in cf defined by different experts. So it is realized that there must be some technique that can minimize the estimation of the error of cf with the iterative use of cf .

In the next section, a proposed modified approach to estimate the error in cf has been presented. It is statistically shown that the proposed approach reduces the error in the enhanced confidence factor of the rule that is available during the initial estimation of the rule confidence.

3.1. Rule promotion methodology

Rule promotion methodology (T1) works on the principle that with higher use of a rule in defining a particular activity, its confidence in giving an enhanced decision dynamically improves. This has been demonstrated using the following three equations 1, 2 and 3 in [22, 23].

They have assumed that for a particular activity, say X_1, having a set of n fuzzy rules, such as α_1, α_2, α_3 … α_n, have confidence factors of $\mathrm{cf}(\alpha_1)$, $\mathrm{cf}(\alpha_2)$, $\mathrm{cf}(\alpha_3)$, …, $\mathrm{cf}(\alpha_n)$ for the respective rules. Then the *weight factor* is

$$\varpi = \frac{1}{\sum_{i=1}^{n} \beta_i}, \qquad (1)$$

where $\beta_1, \beta_2, \beta_3, \ldots, \beta_n$ are the promotional frequencies of these rules. Thus, the rule *promotion factor* becomes

(2) $$\mathrm{pf}(\alpha_i) = \beta_i \varpi.$$

They specified that $\mathrm{pf}(\alpha_i) < 1$ and $\sum \mathrm{pf}(\alpha_i) = 1$ for activity X_i, i.e., the algebraic sum of the promotion factor defined by a set of n rules of a particular activity is always one.

According to them, the existing confidence factor of the rule α_i for activity X_1 is $\mathrm{cf}(\alpha_i)$. Then, for this rule the promoted *confidence factor*

(3) $$\mathrm{pcf}(\alpha_i) = \mathrm{cf}(\alpha_i) + \mathrm{pf}(\alpha_i)[1 - \mathrm{cf}(\alpha_i)]$$

indicates $\mathrm{pcf}(\alpha_i) \le 1$ and $\mathrm{pcf}(\alpha_i) = 1$ implies complete confidence, and $\mathrm{pcf}(\alpha_i) = 0$ gives no confidence in the promoted rule.

3.2. Improvement in rule promotion approach

An original approach has provided a novel way to improve the confidence factor of a rule. The initial confidence factor of a rule must be provided by domain experts. There may be an error in the estimation of the confidence factor of a rule by the expert also. Various experts may have different values for a confidence factor of a rule. This has not been considered in the original approach. This indicates that there may be an error in the declaration/estimation of the confidence factor. The original approach does not focus on the issue how the error deviates during rule promotion. The present study has been undertaken to find out the reduction in the error of initially estimated confidence factor during subsequent rule promotions. In this study it has been found that there is a reduction in the error of the initially estimated confidence factor during the subsequent rule promotion using the original approach, which can be further reduced by improving the original approach using the accumulated error variation or uncertainties in the scaling factor to evaluate the weight factor. The overall variance of the error or uncertainty can be evaluated using the root sum square.

It is a known fact that the short-term and long-term precision errors must be calculated as a Root-Mean-Square (RMS) of the standard deviations of repeated measurements, as mentioned in C.-C. G l ü e r et al. [25]. The root mean sum of the square is the method to reduce the error around the mean value of frequency as readings are spread around the mean true value. To get RMS, the square root of the sum of squares of the observations, divided by the total number of observations (N) is considered. This RMS is a measurement of the error in each of the N observations. It shows how far an estimate of each measurement is from the mean one. This is not an overall error, but it is a typical error. The Root of the Sum of Squares (RSS) is related to RMS excluding the division by N. This type of a combination is used when the sources of errors are combined to determine the overall error.

Also, it is a known fact that the aggregated uncertainty is calculated as the "square root of the sum of the squares" using the absolute uncertainties. This fact has motivated the current work to use RSS in rule promotion methodology to reduce the error in promotion of an initially estimated confidence factor. In (2), scaling of the promotion factor is obtained using (1). In the proposed technique T2, scaling of the promotion factor can be obtained using RSS in (4).

In the improved approach (T2), the weight factor (ϖ) (1) of the rule with reference to the promotional frequencies (β_i) is defined as

$$\varpi = \frac{1}{\sqrt{\sum_{i=1}^{n} \beta_i^2}}. \tag{4}$$

So that the logic sum of squares of promotion factors is always equal to one:

$$\sum \text{pf}^2(\alpha_i) = \sum \left[\frac{\beta_i}{\sqrt{\sum \beta_i^2}} \right]^2 = \frac{\beta_1^2 + \beta_2^2 + \beta_3^2 + \ldots + \beta_n^2}{\left(\sqrt{\beta_1^2 + \beta_2^2 + \beta_3^2 + \ldots + \beta_n^2} \right)^2} = 1.$$

The other equations, viz (2) and (3) remain the same as proposed in [22, 23].

3.3. Testing of a hypothesis

To test the proposed amendment in the error estimation, a database of diseases in rice and its symptoms has been prepared with the help of a plant pathologist [26]. A part of the dataset has been provided in Table 1. Weight/confidence factor (cf) to symptoms has been assigned within the range from 0 up to 1. These weights have been provided in such a way that the confidence level of the symptoms describes the percentage of the chance for presence of a disease in a rice plant. A zero cf indicates that a rule has no confidence in this disease, which implies that the rule does not describe the disease. Factor cf having a value of one describes that the rule defines strongly the disease. The factor ϖ for each rule has been calculated using (4) for the improved method and using the existing (1) of the rule promotion method respectively. Factor pf of each rule is calculated and mentioned in Table 3. Then, the factor pcf of the rule is calculated using (3) and listed in Table 4.

As an example, a series of sessions for rule firing is given in Table 2 for Sheath Blight (the scientific name of Rhizoctonia Solani) disease, as described in S. Kagale et al. [27]. A data base has been prepared and a Rule ID has been defined for the symptoms of a disease as specified in Table 1. Out of these rules, Rule 1011 up to Rule 1018 used consecutively for the diagnosis of the disease, have been listed in Table 2.

Table 1. Some of the Paddy plant diseases with weight of symptoms

Disease	Part of plant	Rule ID	Rule	Weight
Sheath Blight	Sheath	1011	Do the symptoms appear at water level?	0.7
		1012	Are the symptoms present at the border plants mainly?	0.6
		1013	Are the symptoms present on the grass growing on the bunds?	0.8
		1014	Are the Greyish Green lesions with purple margin on the leaf sheath?	0.7
		1015	Do the lesions involve a considerable portion of the leaf sheath?	0.5
		1016	Is the center of the spot greyish white with brown or purple margin?	0.7
		1017	Are the lesions enlarged and irregular?	0.5
		1018	Is the infection seen on culm?	0.3
Sheath Rot	Sheath	1021	Are the symptoms on the uppermost leaf sheath enclosing the panicles?	0.8
		1022	Are the lesions oblong to irregular?	0.5
		1023	Are the lesions greyish brown to light brown?	0.4
		1024	Do the lesions coalesce to cover the entire sheath?	0.6
		1025	Do the panicles emerge or not emerge partially?	0.6
		1026	Does the white powdery growth of fungus appear on the inner side of sheath?	1
False Smut	Grain	1031	Was the weather rainy and cloudy during the flowering period?	0.6
		1032	Are the individual grains transformed into large greenish velvety spore balls?	1
Kernal Smut(Bunt)	Grain	1041	Are the few only grains in the panicles affected?	0.7
		1042	Is a part of the grain usually replaced by black powder mass?	0.9
		1043	Is the black powdery mass scattered on the grains or leaves?	0.7
		1044	Does the disease start at the dough grain or mature grain stage?	0.3
Udabatta	Grain	1051	Does the disease start at the dough grain or mature grain stage?	0.3
		1052	Do the affected panicles emerge as straight spikelets?	0.7
Rice Blast	Leaf, Stem, Panicles	1061	Are the lesions present on the neck of the panicles also?	0.8
		1062	Are the spots spindle shaped?	0.9
		1063	Do the spots or lesions have a greyish centre and brown margins?	0.5
		1064	Is there an application of a high dose of nitrogen fertilizers?	0.5
		1065	Is the variety basmati?	0.7
		1066	Were the symptoms found on the seedling also?	0.5

The factor ϖ for each rule has been calculated using (4) for the improved method and using the existing (1) of the rule promotion method respectively. The factor pf of each rule is calculated and mentioned in Table 3. Then, factor pcf of the rule is calculated using equation (3) and listed in Table 4.

Table 2. Frequencies of usage of rules for sheath of Sheath Blight disease of a paddy crop

Rule	1011	1012	1013	1014	1015	1016	1017	1018
cf	0.7	0.6	0.8	0.7	0.5	0.7	0.5	0.3
β_0	0	0	0	0	0	0	0	0
β_1	1	1	1	0	0	1	1	1
β_2	2	2	1	2	1	1	2	2
β_3	3	3	2	2	1	2	3	3
β_4	4	3	2	2	2	3	3	4
β_5	4	4	3	3	3	4	4	4
β_6	5	5	4	3	4	5	5	4
β_7	6	5	5	4	4	6	5	5
β_8	7	6	4	4	5	7	6	6
β_9	8	7	5	5	6	8	7	7
β_{10}	9	8	6	6	7	9	8	7

3.4. Evaluation of the proposed technique

It is assumed that there is ±10% error in the initial estimation of the weight (cf). The factor pf and pcf are calculated for the true value and with a variation of 10% in the cf of the rules, using (1), (2) and (3) of the existing technique (T1) and using (4), (2) and (3) for the proposed modified technique (T2) respectively. This has been shown in Table 5.

Table 3. Comparison of the pf of existing and improved techniques

	Existing technique (T1)										Improved technique (T2)									
Rule	pf_1	pf_2	pf_3	pf_4	pf_5	pf_6	pf_7	pf_8	pf_9	pf_{10}	pf_1	pf_2	pf_3	pf_4	pf_5	pf_6	pf_7	pf_8	pf_9	pf_{10}
1011	0.170	0.150	0.160	0.170	0.140	0.140	0.150	0.160	0.150	0.150	0.410	0.420	0.430	0.470	0.390	0.400	0.420	0.430	0.420	0.420
1012	0.170	0.150	0.160	0.130	0.140	0.140	0.130	0.130	0.130	0.130	0.410	0.420	0.430	0.360	0.390	0.400	0.350	0.370	0.370	0.370
1013	0.170	0.080	0.110	0.090	0.100	0.110	0.130	0.090	0.090	0.100	0.410	0.210	0.290	0.240	0.290	0.320	0.350	0.250	0.260	0.280
1014	0.000	0.150	0.110	0.090	0.100	0.090	0.100	0.090	0.090	0.100	0.000	0.420	0.290	0.240	0.290	0.240	0.280	0.250	0.260	0.280
1015	0.000	0.080	0.050	0.090	0.100	0.110	0.100	0.110	0.110	0.120	0.000	0.210	0.140	0.240	0.290	0.320	0.280	0.310	0.320	0.330
1016	0.170	0.080	0.110	0.130	0.140	0.140	0.150	0.160	0.150	0.150	0.410	0.210	0.290	0.360	0.390	0.400	0.420	0.430	0.420	0.420
1017	0.170	0.150	0.160	0.130	0.140	0.140	0.130	0.130	0.130	0.130	0.410	0.420	0.430	0.360	0.390	0.400	0.350	0.370	0.370	0.370
1018	0.170	0.150	0.160	0.170	0.140	0.110	0.130	0.130	0.130	0.120	0.410	0.420	0.430	0.470	0.390	0.320	0.350	0.370	0.370	0.330

Table 4. Comparison of the pcf of existing and improved techniques

	Existing technique (T1)										Improved technique (T2)									
Rule	pcf_1	pcf_2	pcf_3	pcf_4	pcf_5	pcf_6	pcf_7	pcf_8	pcf_9	pcf_{10}	pcf_1	pcf_2	pcf_3	pcf_4	pcf_5	pcf_6	pcf_7	pcf_8	pcf_9	pcf_{10}
1011	0.751	0.745	0.748	0.751	0.742	0.742	0.745	0.748	0.745	0.745	0.823	0.826	0.829	0.841	0.817	0.820	0.826	0.829	0.826	0.826
1012	0.668	0.660	0.664	0.652	0.656	0.656	0.652	0.652	0.652	0.652	0.764	0.768	0.772	0.744	0.756	0.760	0.740	0.748	0.748	0.748
1013	0.834	0.816	0.822	0.818	0.820	0.822	0.826	0.818	0.818	0.820	0.882	0.842	0.858	0.848	0.858	0.864	0.870	0.850	0.852	0.856
1014	0.700	0.745	0.733	0.727	0.730	0.727	0.730	0.727	0.727	0.730	0.700	0.826	0.787	0.772	0.787	0.772	0.784	0.775	0.778	0.784
1015	0.500	0.540	0.525	0.545	0.550	0.555	0.550	0.555	0.555	0.560	0.500	0.605	0.570	0.620	0.645	0.660	0.640	0.655	0.660	0.665
1016	0.751	0.724	0.733	0.739	0.742	0.742	0.745	0.748	0.745	0.745	0.823	0.763	0.787	0.808	0.817	0.820	0.826	0.829	0.826	0.826
1017	0.585	0.575	0.580	0.565	0.570	0.570	0.565	0.565	0.565	0.565	0.705	0.710	0.715	0.680	0.695	0.700	0.675	0.685	0.685	0.685
1018	0.419	0.405	0.412	0.419	0.398	0.377	0.391	0.391	0.391	0.384	0.587	0.594	0.601	0.629	0.573	0.524	0.545	0.559	0.559	0.531

Table 5. Error calculated using the two approaches for disease D_1

	Rule	Original			10%				–10%			
		cf	pf	pcf	cf	pf	pcf	% Error	cf	pf	pcf	% Error
T2 approach	1011	0.700	0.410	0.823	0.630	0.410	0.782	-5.018	0.770	0.410	0.864	5.018
	1012	0.600	0.410	0.764	0.540	0.410	0.729	-4.634	0.660	0.410	0.799	4.634
	1013	0.800	0.410	0.882	0.720	0.410	0.835	-5.351	0.880	0.410	0.929	5.351
	1014	0.700	0.000	0.700	0.630	0.000	0.630	-10.000	0.770	0.000	0.770	10.000
	1015	0.500	0.000	0.500	0.450	0.000	0.450	-10.000	0.550	0.000	0.550	10.000
	1016	0.700	0.410	0.823	0.630	0.410	0.782	-5.018	0.770	0.410	0.864	5.018
	1017	0.500	0.410	0.705	0.450	0.410	0.676	-4.184	0.550	0.410	0.735	4.184
	1018	0.300	0.410	0.587	0.270	0.410	0.569	-3.015	0.330	0.410	0.605	3.015
T1 approach	1011	0.700	0.170	0.751	0.630	0.170	0.693	-7.736	0.770	0.170	0.809	7.736
	1012	0.600	0.170	0.668	0.540	0.170	0.618	-7.455	0.660	0.170	0.718	7.455
	1013	0.800	0.170	0.834	0.720	0.170	0.768	-7.962	0.880	0.170	0.900	7.962
	1014	0.700	0.000	0.700	0.630	0.000	0.630	-10.000	0.770	0.000	0.770	10.000
	1015	0.500	0.000	0.500	0.450	0.000	0.450	-10.000	0.550	0.000	0.550	10.000
	1016	0.700	0.170	0.751	0.630	0.170	0.693	-7.736	0.770	0.170	0.809	7.736
	1017	0.500	0.170	0.585	0.450	0.170	0.544	-7.094	0.550	0.170	0.627	7.094
	1018	0.300	0.170	0.419	0.270	0.170	0.394	-5.943	0.330	0.170	0.444	5.943

The results thus obtained are checked for an error with respect to its true value. The error in the factor pcf of each rule has been mentioned in Table 6 using the above mentioned equations. From Table 6 it can be concluded that the initial estimation error of 10% is reduced to 7.74% using the existing technique (T1) and it is reduced to 5.02% using the modified proposed technique (T2), which is applied to Rule 1011. Similarly, the error for the other rules has been calculated. Although there is reduction in the error using the proposed technique, the statistical significance of the error reduction in these two techniques for better disease diagnosis is further confirmed by the Analysis of Variance (ANOVA). The factor pcf for Rule 1011 has been taken from Table 7 and ANOVA (two-factor without replication) has been applied using the descriptive statistical tool of MS-Excel [28].

Table 6: Error table

Rule	Error % age (±10% variation in the initial estimation of weights)															
	T1 (error in ± % age)								T2 (error in ± % age)							
	1011	1012	1013	1014	1015	1016	1017	1018	1011	1012	1013	1014	1015	1016	1017	1018
pcf_1	7.74	7.46	7.96	10.00	10.00	7.74	7.09	5.94	5.02	4.63	5.35	10.00	10.00	5.02	4.18	3.02
pcf_2	7.99	7.73	9.02	7.99	8.52	8.90	7.39	6.30	4.92	4.53	7.51	4.92	6.53	7.25	4.08	2.93
pcf_3	7.86	7.59	8.66	8.50	9.05	8.50	7.24	6.12	4.81	4.43	6.62	6.32	7.54	6.32	3.99	2.85
pcf_4	7.74	8.01	8.90	8.76	8.35	8.24	7.70	5.94	4.41	5.16	7.17	6.89	6.13	5.54	4.71	2.53
pcf_5	8.11	7.87	8.78	8.63	8.18	8.11	7.54	6.48	5.23	4.84	6.62	6.32	5.50	5.23	4.39	3.19
pcf_6	8.11	7.87	8.66	8.76	8.02	8.11	7.54	7.08	5.12	4.74	6.30	6.89	5.15	5.12	4.29	3.89
pcf_7	7.99	8.01	8.43	8.63	8.18	7.99	7.70	6.68	4.92	5.27	5.98	6.43	5.63	4.92	4.81	3.58
pcf_8	7.86	8.01	8.90	8.76	8.02	7.86	7.70	6.68	4.81	5.05	7.06	6.77	5.27	4.81	4.60	3.38
pcf_9	7.99	8.01	8.90	8.76	8.02	7.99	7.70	6.68	4.92	5.05	6.95	6.66	5.15	4.92	4.60	3.38
pcf_{10}	7.99	8.01	8.78	8.63	7.86	7.99	7.70	6.87	4.92	5.05	6.73	6.43	5.04	4.92	4.60	3.79

Table 7. Percentage error in Technique T1 and T2 for rule No 1011

	Rule	pcf_1	pcf_2	pcf_3	pcf_4	pcf_5	pcf_6	pcf_7	pcf_8	pcf_9	pcf_{10}	**Average**
T1	1011	7.74	7.99	7.86	7.74	8.11	8.11	7.99	7.86	7.99	7.99	**7.94**
T2	1011	5.02	4.92	4.81	4.41	5.23	5.12	4.92	4.81	4.92	4.92	**4.91**

Table 8. ANOVA table for Technique T1 and T2 for rule No 1011

ANOVA: Two-factor without replication							
Source of variation	SS	Df	MS	F	P-value	F critical	CV
Factor pcf	0.481	9	0.053	4.503	0.018	3.179	1.71
Techniques (T)	45.91	1	45.91	3866	$4.10^{-13} < 0.001$	5.117	
Error	0.107	9	0.012				
Total	46.5	19					

LSD_{pcf} (0.05) = 0.24, LSD_T (0.05) = 0.11.

4. Results and future work

An improved approach has been statistically tested for significance and compared with the existing methodology using ANOVA and the results are shown in Table 8. As calculated, the *F*-value indicates that there is significant difference between the two techniques for Rule 1011 of the existing (T1) and the proposed (T2). Furthermore, the average promoted confidence factor over ten iterations being significantly less than the average of the existing technique confirms that the proposed technique is significantly better than the existing technique. It has been found that the deployment of the improved technique reduces the errors in the estimation of the confidence factor. In future the proposed technique will be implemented in the development of a web and mobile application for the dissemination of the Agricultural Information to the farmers and other stakeholders by implementing field level testing in real time situations.

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