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Per Field Classifier for Agricultural Applications

by
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I. Introduction

In accordance with general crop planting practice, if an agricultural field has a certain majority of resolution elements classified as "ω_i", then one can feel reasonably sure that the entire field as a whole is in class "ω_i". Based on this observation, we shall formulate a pattern classification procedure for agricultural applications as follows. Let $\{\omega_i\}$ be a set of pattern classes with their distribution $\{F_i\}$ respectively, and let the feature vector x be a random variable under consideration. Then given a set of points $\{x\}$ all from the same field, the problem is to decide to which F_i they belong. We shall propose a distance measure $d(F_i, F_j)$ as a suitable metric of the separation between any two distributions F_i and F_j, and we shall use this metric as a rule for decision making. Let $G(x)$ be the distribution governing $\{x\}$. We shall compare the magnitudes of $\{d(G, F_i)\}$; the distribution F_i which minimizes the distance $d(G, F_i)$ shall be presumed to be the distribution which contains $G(x)$. Therefore, the vector set $\{x\}$ is classified into one of the known classes.

If the distributions concerned are unknown, we shall empirically estimate these distributions F_i based on finite observation on $x \sim \omega_i$.

II. Definition of the Distance

Let $F_i(x)$ and $F_j(x)$ be the distributions of pattern classes ω_i and ω_j respectively, and let $p_i(x)$ and $p_j(x)$ be their probability density functions defined in Ω_x. Then the distance between distributions F_i and F_j is defined as follows:

$$d^2(F_i,F_j) = \int_\Omega (\sqrt{p_i(x)} - \sqrt{p_j(x)})^2\, dx \tag{1}$$

If we define

$$\rho(F_i,F_j) = \int_\Omega \sqrt{p_i(x)} \cdot \sqrt{p_j(x)}\, dx \tag{2}$$

we have

$$d^2(F_i,F_j) = 2 - 2\rho(F_i,F_j) \tag{3}$$

The quantity $\rho(F_i,F_j)$ expresses the correlation between distributions F_i and F_j, and we can use $\rho(F_i,F_j)$ in decision making. It is important to note that to minimize the $d(F_i,F_j)$ is the same as to maximize the $\rho(F_i,F_j)$.

III. Distance in Multivariate Cases

The distance $d(F_i,F_j)$ defined in Equation (1) is applicable to any distribution. We shall now turn to multivariate Gaussian case for agricultural applications. Let Ω_x be an n-dimensional space, and let F_i and F_j be n-dimensional Gaussian distributions with their probability density functions

$$p_i(x) = \frac{1}{(2\pi)^{\frac{n}{2}} |K_i|^{\frac{1}{2}}} \exp\left[-\frac{1}{2}(x-\mu_i)^T K_i^{-1}(x-\mu_i)\right] \tag{4}$$

$$p_j(x) = \frac{1}{(2\pi)^{\frac{n}{2}} |K_j|^{\frac{1}{2}}} \exp\left[-\frac{1}{2}(x - \mu_j)^T K_j^{-1}(x - \mu_j)\right] \tag{5}$$

in which μ_i and K_i are the mean vector and covariance matrix respectively. Substituting Equation (4) and Equation (5) into Equation (2), we obtain

$$\rho(F_i,F_j) = \frac{|K_i^{-1}K_j^{-1}|^{\frac{1}{4}}}{|\frac{1}{2}(K_i^{-1} + K_j^{-1})|^{\frac{1}{2}}}$$

$$\exp\left[\frac{1}{4}(K_i^{-1}\mu_i + K_j^{-1}\mu_j)^T(K_i^{-1} + K_j^{-1})^{-1}(K_i^{-1}\mu_i + K_j^{-1}\mu_j) - \frac{1}{4}(\mu_i^T K_i^{-1}\mu_i + \mu_j^T K_j^{-1}\mu_i)\right] \tag{6}$$

When $K_i = K_j = K$ (equal covariance)

$$\rho(F_i,F_j) = \exp\left[-\frac{1}{8}(\mu_i - \mu_j)^T K^{-1}(\mu_i - \mu_j)\right] \tag{7}$$

When $\mu_i = \mu_j = \mu$

$$\rho(F_i,F_j) = \frac{|K_i^{-1}K_j^{-1}|^{\frac{1}{4}}}{|\frac{1}{2}(K_i^{-1} + K_j^{-1})|^{\frac{1}{2}}} \tag{8}$$

IV. System Implementation and Experimental Results

1. Description of Data

The proposed pattern classification technique in multiclass pattern recognition has been tested on IBM System 360/Model 44 digital computer by performing crop classification experiments. The data used in these experiments was gathered by an airborne multichannel optical-mechanical scanner. The output of this particular scanner provides twelve electrical signals, each one of which is proportional to radiant energy from the scene in a different spectral band. The twelve bands cover the range from 0.4 - 1.0 microns in the visible and near infrared portions of the spectrum. By simultaneously sampling the output of twelve channels, one obtains a vector which contains all the spectral information available about a given resolution element on the ground.

From the histogram study, the data can be fairly reasonably modeled by multivariate Gaussian distributions with unequal covariance matrices. The mean vector and covariance matrix of each class can be estimated from an adequate number of training samples as the sample mean and the sample covariance respectively.

2. General Procedure

(1) From the ground truth data, we first estimated the mean vectors and covariance matrices for all classes or subclasses considered. These estimations were used to characterize the distributions of all subclasses considered.

(2) For any given agricultural field with unknown crop types present, we assumed that the distribution of the feature vector is multivariate Gaussian. Therefore, we can obtain the empirical distribution by estimating the mean and the covariance as the sample mean and the sample covariance.

(3) We calculate the correlation function $\rho(\cdot,\cdot)$ between the empirical distribution of a particular test field and each of the distributions characterizing the known classes in accordance with the formula expressed in Equation (6).

(4) The final decision is made by choosing the class which maximizes the correlation function $\rho(\cdot,\cdot)$

3. Experimental Results

In order to evaluate the performance of the per field classifier, agricultural fields from areas C-2, C-3 and C-4 were used as test fields. All 12 features were employed by the per field classifier.

(1) Area C-4, July 1966 Data

Based on the histogram study, five subclasses each were chosen to represent the soybeans, the corn and the pasture. The stubble was represented by four subclasses. This was due to the multimodal distribution of each of the four classes. The statistical parameters were estimated from 4,832 training samples. The classification results are summarized in Table 1. The same data was classified by the MLDR (Maximum Likelihood Decision Rule) classifier, LARSYSAA, using the same set of training statistics, and these results together with the per field classification results are shown in Table 2 for comparison.

Table 1

Summary of per field classification results
(Data used taken from Area C-4 in July 1966)

Class	No. of Fields	Number of Fields Classified into			
		Soybeans	Corn	Pasture	Stubble
Soybeans	19	17	2	0	0
Corn	31	1	30	0	0
Pasture	18	0	0	18	0
Stubble	13	0	0	3	10

Total: 81

Table 2

Summary of MLDR classification results
(Data used taken from Area C-4 in July 1966)

Spectral bands used were: 0.40-0.44, 0.52-0.55, 0.62-0.66, 0.66-0.72, 0.72-0.80

Classification Summary by Test Fields

Class	No. of Samples	Percent Correct	No. of Samples Classified into					Per Field	60% Classifier
			Soyb	Corn	Past	Stub	Thrs		
Soyb	405	88.9	360	18	27	0	0	Soyb	Soyb
Soyb	361	93.1	336	11	2	8	4	Soyb	Soyb
Soyb	220	87.3	192	28	0	0	0	Soyb	Soyb
Soyb	320	76.6	245	30	45	0	0	Soyb	Soyb
Soyb	180	87.2	157	11	4	7	1	Soyb	Soyb
Soyb	297	76.1	226	38	11	0	22	Soyb	Soyb
Soyb	192	99.0	190	2	0	0	0	Soyb	Soyb
Soyb	672	92.7	623	31	18	0	0	Soyb	Soyb
Soyb	294	86.7	255	38	0	0	1	Soyb	Soyb
Soyb	80	18.8	15	56	3	5	1	Corn	Corn
Soyb	126	42.9	54	51	17	4	0	Corn	----
Soyb	638	84.6	540	70	2	0	26	Soyb	Soyb
Soyb	406	94.8	385	14	0	0	7	Soyb	Soyb
Soyb	280	71.4	200	50	30	0	0	Soyb	Soyb
Soyb	68	98.5	67	1	0	0	0	Soyb	Soyb
Soyb	85	95.3	81	2	1	1	0	Soyb	Soyb
Soyb	304	69.4	211	60	11	1	21	Soyb	Soyb
Soyb	224	61.6	138	36	30	20	0	Soyb	Soyb
Soyb	150	84.0	126	18	0	3	3	Soyb	Soyb
Corn	224	77.7	40	174	3	0	7	Corn	Corn

Table 2 (continued)

Class	No. of Samples	Percent Correct	No. of Samples Classified into Soyb	Corn	Past	Stub	Thrs	Per Field	60% Classifier
Corn	286	89.5	27	256	3	0	0	Corn	Corn
Corn	240	95.4	11	229	0	0	0	Corn	Corn
Corn	252	73.8	62	186	0	0	4	Corn	Corn
Corn	344	92.7	17	319	2	6	0	Corn	Corn
Corn	300	93.3	20	280	0	0	0	Corn	Corn
Corn	299	88.0	36	263	0	0	0	Corn	Corn
Corn	736	91.6	47	674	15	0	0	Corn	Corn
Corn	552	88.6	50	489	13	0	0	Corn	Corn
Corn	294	88.1	32	259	0	1	2	Corn	Corn
Corn	112	85.7	16	96	0	0	0	Corn	Corn
Corn	342	78.4	17	268	57	0	0	Corn	Corn
Corn	168	52.4	70	88	10	0	0	Corn	----
Corn	285	63.9	95	182	1	0	7	Corn	Corn
Corn	102	42.2	57	43	0	0	2	Soyb	----
Corn	273	28.6	195	78	0	0	0	Corn	Soyb
Corn	348	69.0	78	240	30	0	0	Corn	Corn
Corn	100	98.0	1	98	0	1	0	Corn	Corn
Corn	416	83.9	44	349	4	19	0	Corn	Corn
Corn	800	79.5	133	636	7	24	0	Corn	Corn
Corn	182	42.3	105	77	0	0	0	Corn	----
Corn	266	37.6	162	100	0	0	4	Corn	Soyb
Corn	204	96.6	2	197	0	5	0	Corn	Corn
Corn	198	27.3	134	54	0	0	10	Corn	Soyb
Corn	252	84.5	5	213	0	34	0	Corn	Corn
Corn	418	88.8	22	371	25	0	0	Corn	Corn
Corn	210	91.0	6	191	12	1	0	Corn	Corn
Corn	168	92.9	11	156	1	0	0	Corn	Corn
Corn	90	96.7	2	87	1	0	0	Corn	Corn
Corn	90	97.8	0	88	2	0	0	Corn	Corn
Corn	324	100.0	0	324	0	0	0	Corn	Corn
Past	408	97.3	0	0	397	6	5	Past	Past
Past	63	100.0	0	0	63	0	0	Past	Past
Past	276	92.8	5	0	256	15	0	Past	Past
Past	280	76.1	36	0	213	20	11	Past	Past
Past	323	71.5	60	31	231	1	0	Past	Past
Past	190	27.4	118	0	52	20	0	Past	Soyb
Past	180	60.6	0	0	109	71	0	Past	Past
Past	360	87.5	5	0	315	40	0	Past	Past
Past	288	27.8	177	7	80	24	0	Past	Soyb
Past	165	11.5	8	2	19	134	2	Past	Stub
Past	231	98.7	0	0	228	3	0	Past	Past
Past	242	82.2	11	0	199	32	0	Past	Past
Past	665	89.9	58	3	598	6	0	Past	Past
Past	300	76.7	0	0	230	70	0	Past	Past
Past	594	81.0	5	0	481	101	7	Past	Past
Past	162	3.7	38	8	6	110	0	Past	Stub
Past	200	92.5	11	0	185	4	0	Past	Past

Table 2 (concluded)

Class	No. of Samples	Percent Correct	No. of Samples Classified into Soyb	Corn	Past	Stub	Thrs	Per Field	60% Classifier
Past	306	97.4	1	2	298	5	0	Past	Past
Stub	259	95.4	1	1	9	247	1	Stub	Stub
Stub	260	72.7	0	0	71	189	0	Past	Stub
Stub	160	22.5	6	1	115	36	2	Past	Past
Stub	171	94.7	0	0	9	162	0	Stub	Stub
Stub	266	95.1	0	0	13	253	0	Stub	Stub
Stub	180	94.4	0	0	10	170	0	Stub	Stub
Stub	68	92.6	3	2	0	63	0	Stub	Stub
Stub	220	99.5	0	0	1	219	0	Stub	Stub
Stub	378	47.6	34	0	155	180	9	Past	----
Stub	243	90.5	11	0	0	220	12	Stub	Stub
Stub	315	82.2	46	0	10	259	0	Stub	Stub
Stub	234	98.3	4	0	0	230	0	Stub	Stub
Stub	189	85.2	27	0	0	161	1	Stub	Stub
Total	22353		6563	7687	4740	3191	172		

Overall Performance = 79.7

Classification Summary by Test Classes

Class	No. of Samples	Percent Correct	No. of Samples Classified into Soyb	Corn	Past	Stub	Thrs
Soyb	5302	83.0	4401	565	201	49	86
Corn	8875	79.6	1497	7065	186	91	36
Past	5233	75.7	533	53	3960	662	25
Stub	2943	81.2	132	4	393	2389	25
Total	22353		6563	7687	4740	3191	172

Overall Performance = 79.7
Average Performance by Class = 79.9

(2) Area C-3, July 1966 Data

Soybeans, corn, stubble, pasture mixtures and water are the four classes to be classified in area C-3. Due to different crop type and growing condition of the soybeans and the corn, each of them was represented by three subclasses. The pasture and the stubble were considered as a single class because of their closeness in distribution. The statistical parameters were estimated from 3,490 training samples. The classification results are summarized in Table 3. The same data was classified by the MLDR classifier using the same set of training statistics, and these results together with the per field classification results are shown in Table 4 for easy comparison.

Table 3

Summary of per field classification results
(Data used taken from Area C-3 in July 1966)

Class	No. of Fields	Number of Fields Classified into			
		Soybeans	Corn	Mixture	Water
Soybeans	13	11	1	1	0
Corn	10	0	9	1	0
Mixture	18	1	0	17	0
Water	3	0	0	0	3
Total:	44				

Table 4

Summary of MLDR classification results
(Data used taken from Area C-3 in July 1966)

Spectral bands used were: 0.66-0.72, 0.72-0.80, 0.80-1.00

Classification Summary by Test Fields

Class	No. of Samples	Percent Correct	No. of Samples Classified into					Per Field	60% Classifier
			Soyb	Corn	Mix	Water	Thrs		
Soyb	90	0.0	0	0	87	0	3	Past	Past
Soyb	270	24.4	66	204	0	0	0	Soyb	Corn
Soyb	105	100.0	105	0	0	0	0	Soyb	Soyb
Soyb	121	84.3	102	19	0	0	0	Soyb	Soyb
Soyb	168	75.6	127	41	0	0	0	Soyb	Soyb

Table 4 (Concluded)

Class	No. of Samples	Percent Correct	No. of Samples Classified into Soyb	Corn	Mix	Water	Thrs	Per Field	60% Classifier
Soyb	90	38.9	35	45	10	0	0	Soyb	-----
Soyb	238	98.7	235	3	0	0	0	Soyb	Sovb
Soyb	70	68.6	48	22	0	0	0	Soyb	Sovb
Soyb	80	83.7	67	13	0	0	0	Soyb	Soyb
Soyb	182	68.1	124	58	0	0	0	Soyb	Sovb
Soyb	660	55.9	369	137	154	0	0	Soyb	-----
Soyb	117	11.1	13	104	0	0	0	Corn	Corn
Soyb	189	79.9	151	38	0	0	0	Soyb	Soyb
Corn	196	89.8	20	176	0	0	0	Corn	Corn
Corn	140	93.6	7	131	2	0	0	Corn	Corn
Corn	171	31.6	117	54	0	0	0	Corn	Soyb
Corn	91	9.9	82	9	0	0	0	Corn	Soyb
Corn	100	91.0	9	91	0	0	0	Corn	Corn
Corn	143	58.0	60	83	0	0	0	Past	-----
Corn	70	70.0	21	49	0	0	0	Corn	Corn
Corn	66	89.4	7	59	0	0	0	Corn	Corn
Corn	120	93.3	8	112	0	0	0	Corn	Corn
Corn	91	100.0	0	91	0	0	0	Corn	Corn
Mix	120	100.0	0	0	120	0	0	Mix	Mix
Mix	360	100.0	0	0	360	0	0	Mix	Mix
Mix	230	100.0	0	0	230	0	0	Mix	Mix
Mix	275	100.0	0	0	275	0	0	Mix	Mix
Mix	182	75.8	44	0	138	0	0	Mix	Mix
Mix	90	100.0	0	0	90	0	0	Mix	Mix
Mix	80	91.2	7	0	73	0	0	Mix	Mix
Mix	80	100.0	0	0	80	0	0	Mix	Mix
Mix	91	63.7	18	15	58	0	0	Soyb	Mix
Mix	100	92.0	7	1	92	0	0	Mix	Mix
Mix	126	100.0	0	0	126	0	0	Mix	Mix
Mix	132	0.0	25	107	0	0	0	Mix	Corn
Mix	169	99.4	1	0	168	0	0	Mix	Mix
Mix	96	100.0	0	0	96	0	0	Mix	Mix
Mix	168	100.0	0	0	168	0	0	Mix	Mix
Mix	117	100.0	0	0	117	0	0	Mix	Mix
Mix	117	100.0	0	0	117	0	0	Mix	Mix
Mix	192	100.0	0	0	192	0	0	Mix	Mix
Water	52	100.0	0	0	0	52	0	Water	Water
Water	28	96.4	0	0	1	27	0	Water	Water
Water	21	90.5	0	0	1	19	1	Water	Water
Total	6394		1875	1662	2755	98	4		

Overall Performance = 76.6

Classification Summary by Test Classes

Class	No. of Samples	Percent Correct	No. of Samples Classified into Sovb	Corn	Mix	Water	Thrs
Soyb	2380	60.6	1442	684	251	0	3
Corn	1188	72.0	331	855	2	0	0
Mix	2725	91.7	102	123	2500	0	0
Water	101	97.0	0	0	2	98	1
Total	6394		1875	1662	2755	98	4

Overall Performance = 76.6

Average Performance by Class = 80.3

(3) Area C-2, September 1966 Data

Sovbeans, corn, pasture, stubble and water were classified in area C-2. The statistical parameters were estimated from 3,094 training samples. The classification results are summarized in Table 5. The same set of data was classified by the MLDR classifier with the same set of training statistics, and the classification results together with the per field classification results are shown in Table 6.

Table 5

Summary of per field classification results
(Data used taken from Area C-2 in Sept. 1966)

Class	No. of Fields	Number of Fields Classified into				
		Soybeans	Corn	Pasture	Stubble	Water
Soybeans	12	8	4	0	0	0
Corn	14	1	13	0	0	0
Pasture	13	0	0	13	0	0
Stubble	11	0	1	1	9	0
Water	3	0	0	0	0	3
Total:	53					

Table 6

Summary of MLDR classification results
(Data used taken from Area C-2 in Sept. 1966)

Spectral bands used were: 0.40-0.44, 0.48-0.50, 0.52-0.55, 0.62-0.66, 0.66-0.72

Classification Summary by Test Fields

Class	No. of Samples	Percent Correct	No. of Samples Classified into						Per Field	60% Classifier
			Soyb	Corn	Past	Stub	Wtr	Thrs		
Soyb	114	95.6	109	4	1	0	0	0	Soyb	Soyb
Soyb	560	77.5	434	114	8	0	0	4	Soyb	Soyb
Soyb	96	95.8	92	3	1	0	0	0	Soyb	Soyb

Table 6 (continued)

Class	No. of Samples	Percent Correct	No. of Samples Classified into Soyb	Corn	Past	Stub	Wtr	Thrs	Per Field	60% Classifier
Soyb	594	16.0	95	479	3	14	0	3	Corn	Corn
Soyb	126	88.1	111	0	15	0	0	0	Soyb	Soyb
Soyb	306	94.1	288	18	0	0	0	0	Soyb	Soyb
Soyb	135	97.0	131	1	0	0	0	3	Soyb	Soyb
Soyb	338	8.6	29	303	0	5	0	1	Corn	Corn
Soyb	338	12.1	41	280	17	0	0	0	Soyb	Corn
Soyb	342	92.7	317	7	7	0	0	11	Corn	Soyb
Soyb	342	89.8	307	35	0	0	0	0	Soyb	Soyb
Soyb	513	0.0	0	456	47	10	0	0	Corn	Corn
Corn	95	96.8	0	92	0	3	0	0	Corn	Corn
Corn	324	69.1	96	224	3	1	0	0	Corn	Corn
Corn	340	87.6	40	298	1	1	0	0	Corn	Corn
Corn	836	93.8	0	784	1	51	0	0	Corn	Corn
Corn	140	92.9	6	130	0	4	0	0	Corn	Corn
Corn	110	21.8	76	24	7	3	0	0	Corn	Soyb
Corn	216	93.1	12	201	3	0	0	0	Corn	Corn
Corn	242	83.1	1	201	8	32	0	0	Corn	Corn
Corn	64	95.3	0	61	0	3	0	0	Corn	Corn
Corn	72	56.9	26	41	1	0	0	4	Corn	----
Corn	84	16.7	58	14	2	0	0	10	Soyb	Soyb
Corn	286	68.5	60	196	18	0	0	12	Corn	Corn
Corn	441	90.9	21	401	9	0	0	10	Corn	Corn
Corn	468	65.6	0	307	33	125	0	3	Corn	Corn
Past	76	81.6	0	1	62	13	0	0	Past	Past
Past	72	94.4	0	0	68	4	0	0	Past	Past
Past	630	91.4	19	0	576	29	0	6	Past	Past
Past	735	92.5	23	16	680	16	0	0	Past	Past
Past	255	96.5	9	0	246	0	0	0	Past	Past
Past	396	88.6	0	0	351	45	0	0	Past	Past
Past	240	92.1	0	0	221	19	0	0	Past	Past
Past	288	59.7	0	0	172	115	0	1	Past	----
Past	210	9.0	0	3	19	188	0	0	Past	Stub
Past	72	63.9	0	1	46	20	2	3	Past	Past
Past	176	65.9	0	6	116	54	0	0	Past	Past
Past	198	51.5	0	72	102	13	5	6	Past	----
Past	260	71.5	2	21	186	12	1	38	Past	Past
Stub	123	95.1	0	0	6	117	0	0	Stub	Stub
Stub	615	91.9	0	0	50	565	0	0	Stub	Stub
Stub	450	0.7	8	12	352	3	0	75	Stub	Past
Stub	132	42.4	0	2	74	56	0	0	Stub	----
Stub	120	28.3	0	19	61	34	0	6	Stub	----
Stub	420	0.5	0	418	0	2	0	0	Corn	Corn
Stub	288	95.1	0	2	12	274	0	0	Stub	Stub
Stub	285	98.6	0	0	4	281	0	0	Stub	Stub
Stub	459	27.9	0	7	324	128	0	0	Stub	Past
Stub	700	88.9	0	2	62	622	0	14	Stub	Stub
Stub	100	38.0	0	1	58	38	1	2	Past	----

Table 6 (concluded)

Class	No. of Samples	Percent Correct	No. of Samples Classified into Soyb	Corn	Past	Stub	Wtr	Thrs	Per Field	60% Classifier
Water	68	100.0	0	0	0	0	68	0	Water	Water
Water	39	97.4	0	0	1	0	38	0	Water	Water
Water	27	100.0	0	0	0	0	27	0	Water	Water
Total	14956		2411	5257	4034	2900	142	212		

Overall Performance = 67.0

Classification Summary by Test Classes

Class	No. of Samples	Percent Correct	No. of Samples Classified into Soyb	Corn	Past	Stub	Wtr	Thrs
Soyb	3804	51.4	1954	1700	99	29	0	22
Corn	3718	80.0	396	2974	86	223	0	39
Past	3608	78.9	53	120	2845	538	8	54
Stub	3692	57.4	8	463	1003	2120	1	97
Water	134	99.3	0	0	1	0	133	0
Total	14956		2411	5257	4034	2900	142	212

Overall Performance = 67.0
Average Performance by Class = 73.4

V. Summary

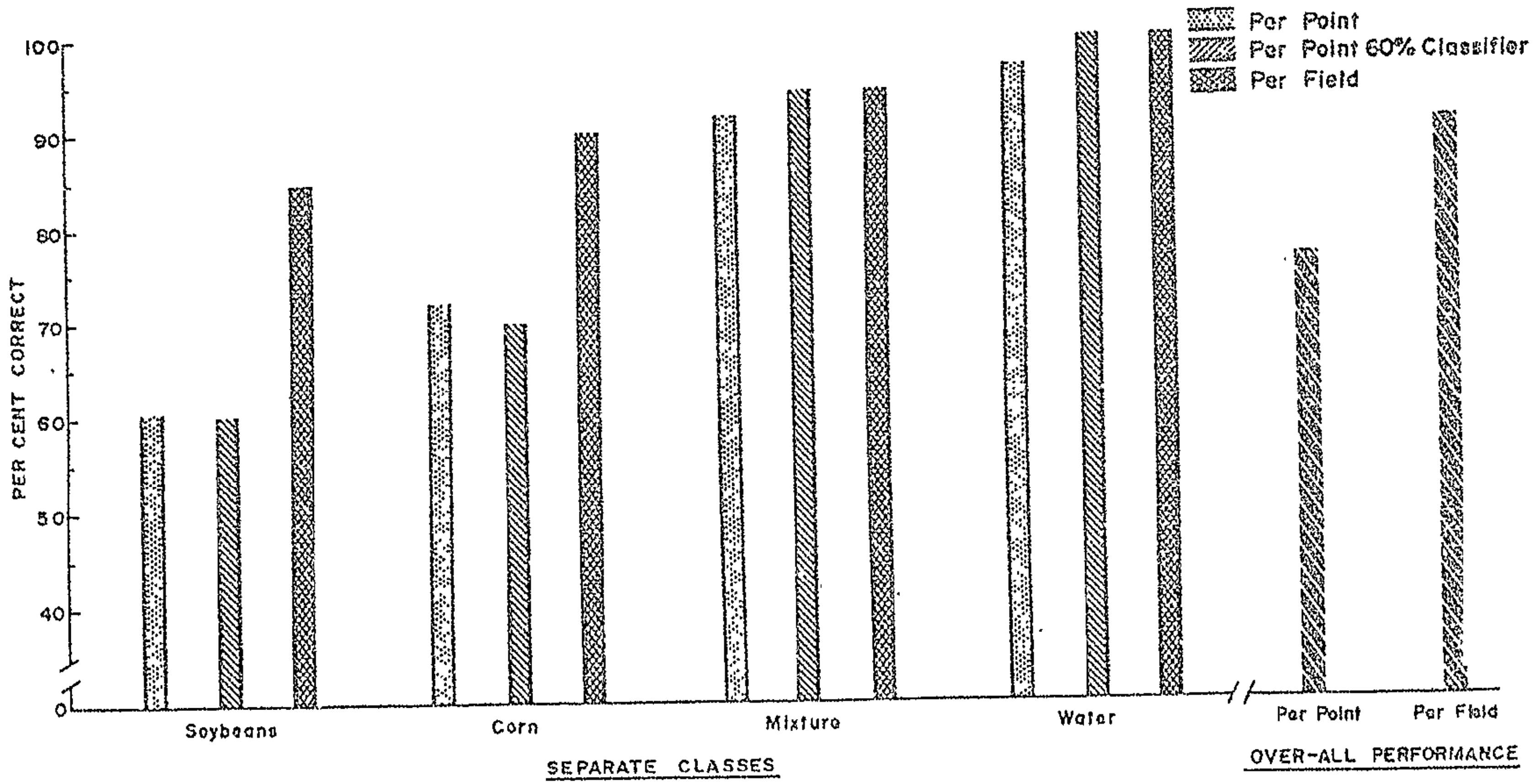
The results are summarized in the bar graphs of Figures 1, 2, and 3. As far as the given data is concerned, the performance of the proposed per field classifier is considered to be very satisfactory. We have not made any attempt to check the assumption of Gaussian distribution to justify the simplified classification scheme employed in this report, but the classification results encourage us to further test the applicability of the per field classifier to agricultural applications.

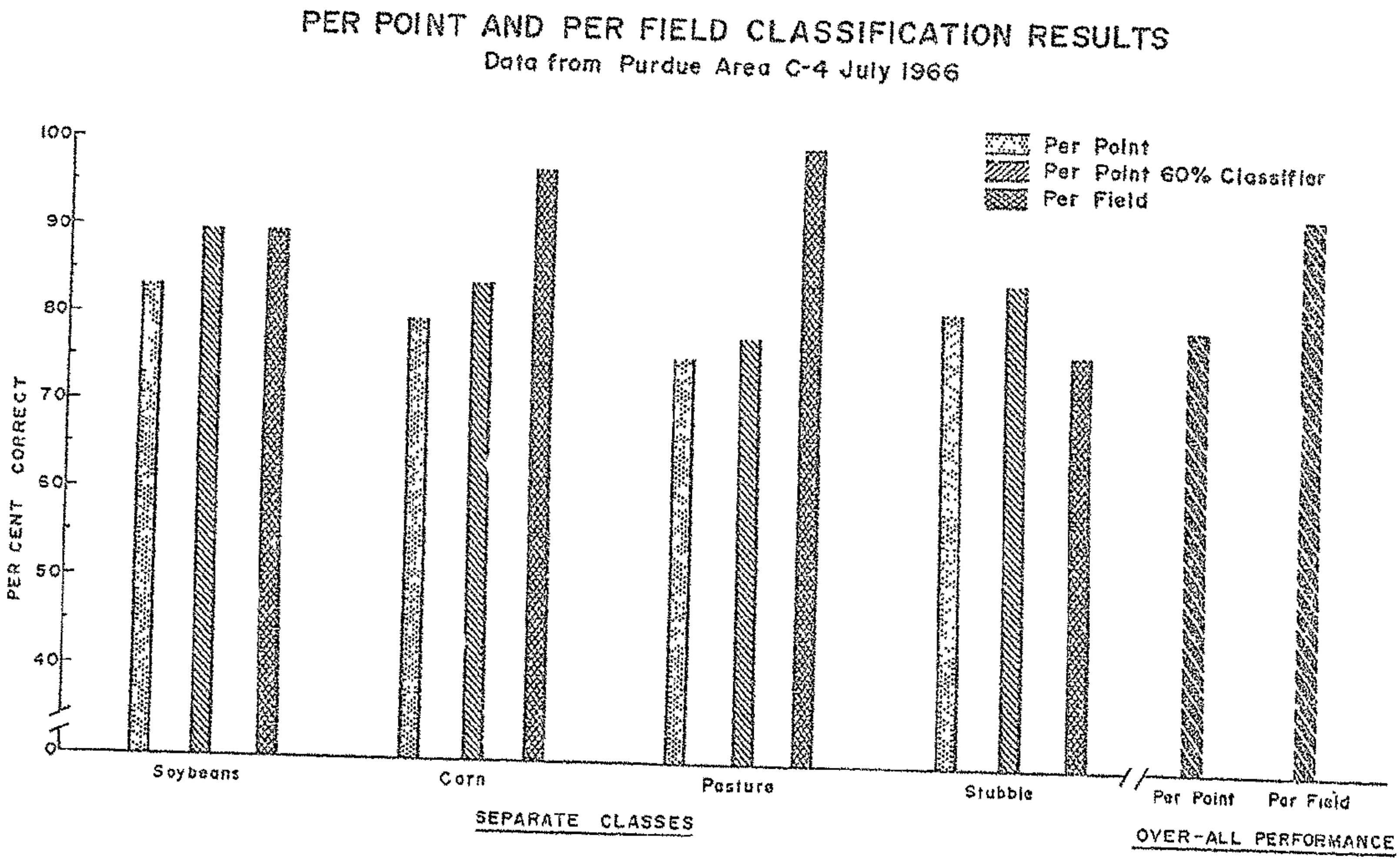
REFERENCE

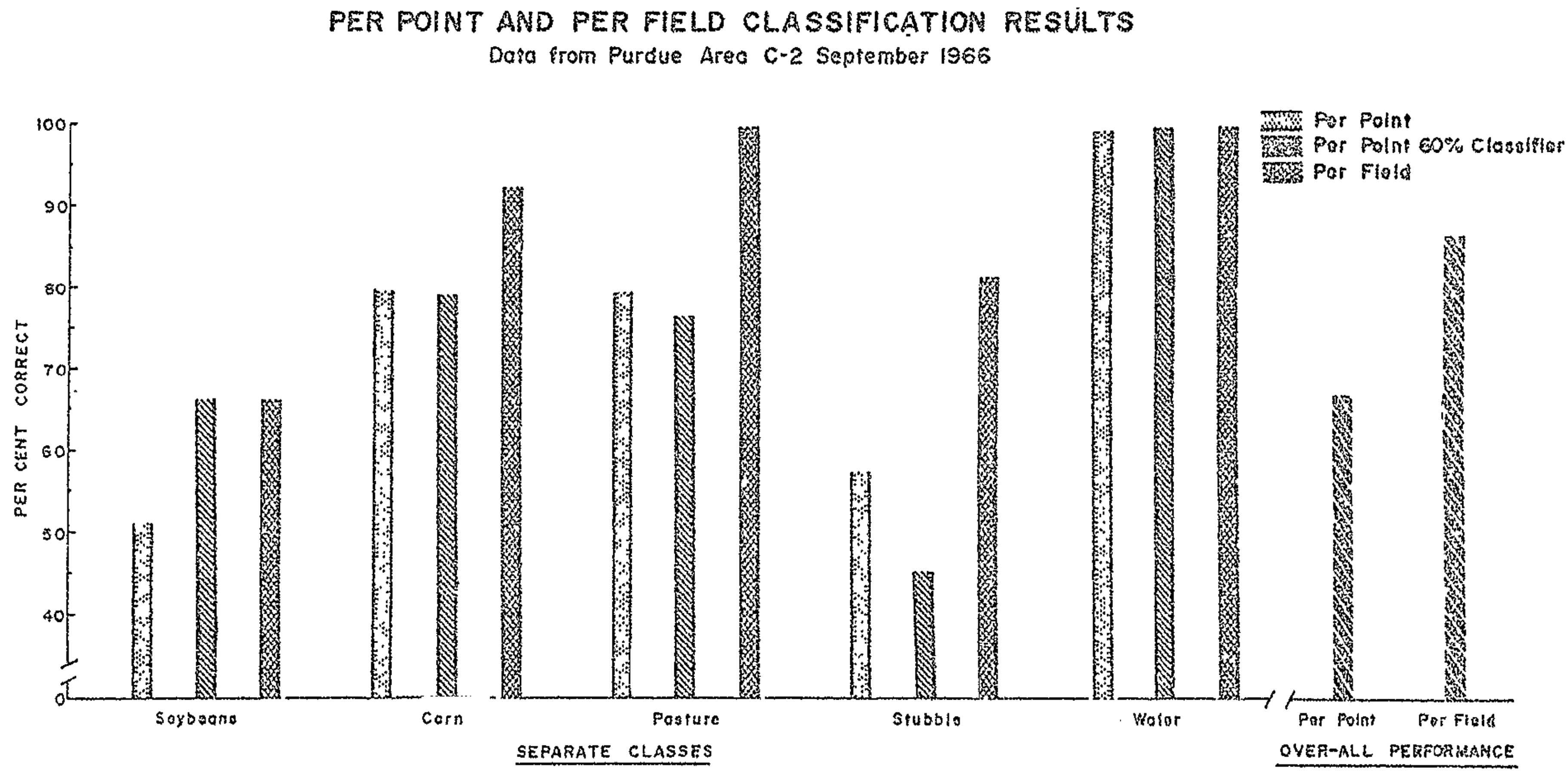
1. K. Matusita, "Classification Based on Distance in Multivariate Gaussian Cases," Fifth Berkeley Symposium on Mathematical Statistics and Probability, Volume 1, Part 1, 1965.

PER POINT AND PER FIELD CLASSIFICATION RESULTS

Data from Purdue Area C-3 July 1966




PER POINT AND PER FIELD CLASSIFICATION RESULTS
Data from Purdue Area C-4 July 1966
PER CENT CORRECT
100
90
80
70
60
50
40
0
Per Point
Per Point 60% Classifier
Per Field
Soybeans
Corn
Pasture
Stubble
SEPARATE CLASSES
Per Point
Per Field
OVER-ALL PERFORMANCE


PER POINT AND PER FIELD CLASSIFICATION RESULTS
Data from Purdue Area C-2 September 1966
Per Point
Per Point 60% Classifier
Per Field
PER CENT CORRECT
100
90
80
70
60
50
40
0
Soybeans
Corn
Pasture
Stubble
Water
Per Point
Per Field
SEPARATE CLASSES
OVER-ALL PERFORMANCE