Robust Face Recognition over Rotation

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ABSTRACT

An inspiring announcement made by Unique Identification Authority of India (UIDAI) on 6th June 2025, that there are two hundred and eleven crore biometric authenticated transactions are made in May 2025. Biometrics are ubiquitous and face is vital for smart applications because of the nonintrusive virtue and works better in non-cooperative environment. In this paper, we propose a robust biometric algorithm to recognize human faces towards the variation of rotation angles. The input images are refined to extract face through Robert's edge detection and cropping. It removes the background information, which is redundant. Unique statistical features are extracted through matrix norm, standard deviation, peak to peak filtering and Normalized Gray-Level Co-Occurrence Matrix (NGLCM). The obtained results are simply outperforms over other conventional approaches.

Keywords: *Smart Campus, Robust, Rotation, Face recognition*

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I. INTRODUCTION

The academic landscape is expecting more from the emerging technologies. The campuses should also be agile enough to handle drastic changes such as industry expectations, student quality, maintaining standards, curriculum up gradation against to statutory guidelines, Handling diversified student community, Incorporation of necessary skills towards different Job profile etc. One needs to create a conducive environment to monitor and smooth conduct of campus activities. The campus facilities are to be strengthened with Smart technologies in classrooms [1], corridors, library [2], office, canteen and other campus locations. The applications include but not limited to academic campuses, security [3], banking, forensics, industry [4], law enforcement and others.

In contrast to the challenges such as Illumination, Pose, occlusion, expression, range and others, it is essential to prove robustness [5] in verification and authentication process to trust on the technology or service. Rotation [6] or tilt is also considered as in influencing factor on the recognition process. Dominantly the feature extraction plays imperative role in the entire recognition scenario. Real time [7] recognition requires more vibrant resources to yield the results with better fidelity.

Contribution: The proposed approach utilizes the potential of statistical matrix features. The peak to peak processing and NGLCM have rendered distinct features. The synergy of attributes fusion has influenced the results.

II. LITERATURE SURVEY

Xiaoyang Tan, et. al., [8] surveyed on single sample size problem through *ad hoc* methods. Various methods with challenges for human face recognition are discussed. Against to the challenges such as difficulty in acquiring many samples and lesser images availability will have vital impact on success rate. The dimension reduction techniques are deployed for processing time and memory requirements are significant factors. The efficacy of several techniques is compared on distinct facial datasets. S Rajarajeswari and Hassan srinivas ranjitha [9] have developed a highly intelligent tool that combines cutting-edge quantum processing principles with traditional computer vision approaches to handle a variety of face detection and identification tasks. The developed streamlit webRTC allows real time video streaming, PIL is utilized for image processing. The uploaded photographs are used to build a face dataset or train a face recognition algorithm. Another important feature is real-time face identification, in which the software uses the Haar Cascade Classifier to identify faces in a video stream. Local Binary Patterns Histograms are used to train the model. It improves the identification of important face characteristics over conventional techniques by utilizing quantum parallelism.

Anjankumar kamalapur et. al., [10], have introduced a modern approach to student attendance management by harnessing the capabilities of face recognition technology and OpenCV. With capabilities including multiple face recognition support, real-time face detection and recognition, and easy connection with current attendance systems. It has the potential improvement in operational efficiency in educational sector by modernizing attendance management practices. Shivamrawatet. al. [11], developed a easiest and secured system for marking attendance with null proxies. The proposed system is simple to use, reliable, and scalable attendance solution for educational institutions and other organizations. It is very much hectic to take attendance by calling out individual names or roll numbers in universities, if the strength is more. The proposed process is more efficient for the busy world and will save a lot of time. The proposed system significantly reduces manual effort, ensures accuracy, and operates efficiently in real-time environments.

Jiashu liao et. al., [12], have introduced a tool called self-supervised frontalization and rotation GAN (FRGAN), from a non-frontal face image to a frontal face image is synthesized. It is rotated back for self supervision of the synthesized image. The original pose is observed for adversarial losses and reconstruction. FRGAN uses a parameter-free data augmentation strategy called the Random Swap, in which the reconstructed and input images are exchanged using key facial regions. The quantitative and qualitative experiments on benchmark datasets have proved performance improvement over other the state-of-the-art methods.

III. PROPOSED METHOD

In this Section, the proposed Robust Face Recognition over Rotation (RFRR) model with different steps is explained as shown in Figure 1. It includes majorly the database or repository of images, preprocessing, extraction of features and features comparison of known repository and test images.

1) Repository or Database: [13] Kinect database consists of a total 468 multimodal images of 52 persons / subjects for different lighting variations with nine different types of expressions and occlusion. Nine images of 52 persons with 14 female and 38 male are collected in two different sessions in fifteen days difference. The occlusion in wearing glasses, mouth, paper, eyes, left profile, right profile, opening mouth, smile and neutral expressions are recorded. In EURECOM institute laboratory, the images at one meter distance are acquired. Each pixel is of 24 bit depth with image size of 256*256 in bitmap format. All 52 persons of the KINECT database are utilized for checking the proposed work.

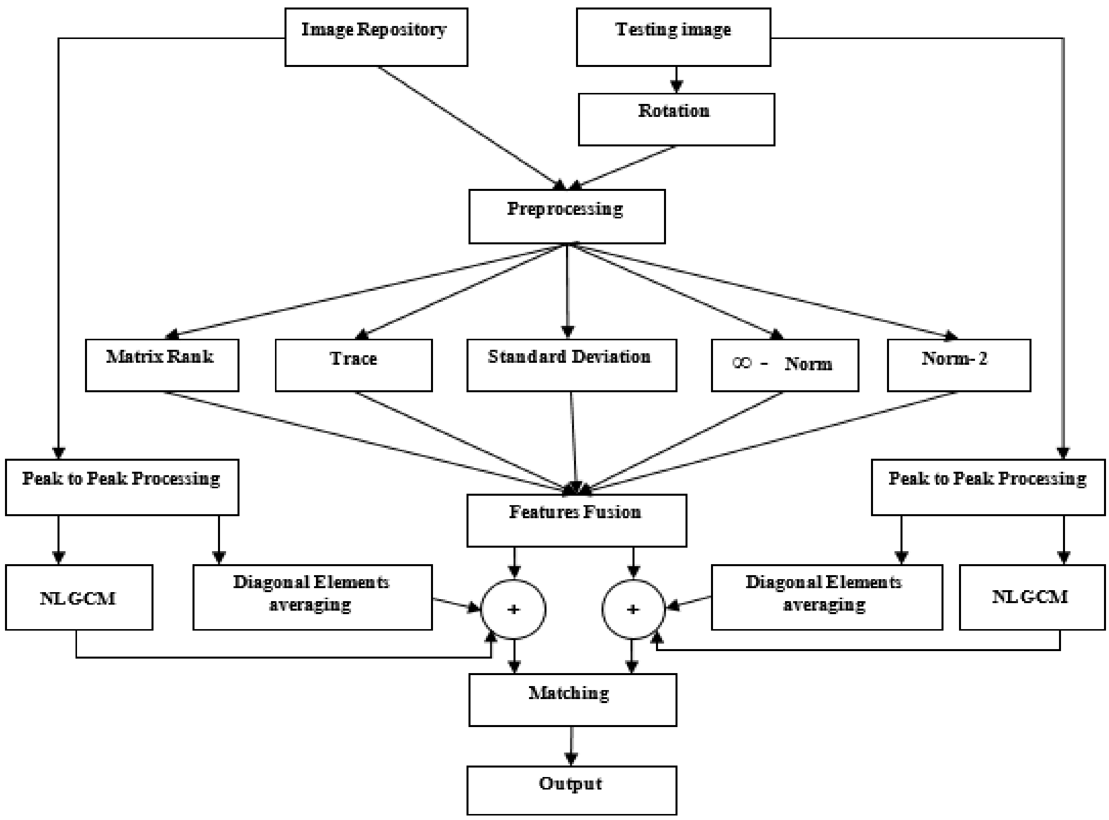
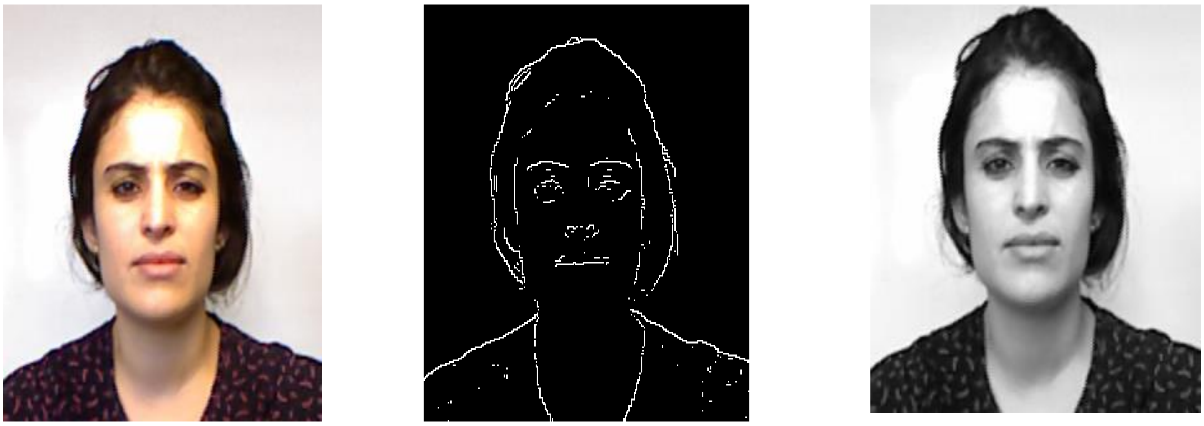


Figure 1. Block diagram of the proposed RFRR model

To create database of known persons the images of 29 persons are taken and for additional performance check left out 23 subject samples are utilized. 9^{th} image of each person is used as probe image. Performance is tested with five trained images and test image is rotated both in clockwise and counterclockwise.

2) Pre-processing:

It is to refine the available images for redundancy such that more precise face images are transferred to next step. Figure 2 shows the input Image and result of preprocessing on input image respectively in 2(a), 2(b) and 2(c).The different steps of preprocessing are; (i) color to intensity optional conversion, (ii) Applying Robert's edge operator [14], (iii) Segmentation, and (iv) Resizing. Any type of input image is converted to gray will reduce the dimension with appreciable quality. Roberts's mask is used to elicit edges. Edges are extracted through the highest gradient value across the mask at any given point and the input image.



2(a) Input image 2(b) Edge detection 2(c) Output

Figure 2. Pre-processing result

The Robert`s mask is effective to refine the facial part in the input image through segmentation. The precise faces are cropped in segmentation as the face boundaries are identified in previous step. Cropping produces different sizes of images, hence they are uniformly resized to 50*50. The consistency of accuracy of proposed method is observed by rotating only the test images in terms of clock wise or anti-clock wise manner.

3) Feature extraction

It is very much important to reduce the preprocessed image in to exclusive fewer size vectors, which uniquely represent preprocessed image. The process of achieving dimensionality reduction with distinct attributes is discussed in this section. The 50*50 preprocessed image is divided into 5*5 sizes each of ten equal non-overlapping segments. Rank of the matrix, trace, standard deviation, infinite norm and matrix 2-norm are separately computed on each 5*5 segment. These obtained attributes or features are averaged algebraically to get one set of features as in Table 1 with average 1 parameter. The number of linearly independent columns or rows of a matrix is said as rank of a matrix [15]. Trace is the sum of diagonal elements of the matrix under consideration. Similarly the Standard Deviation (SD) of matrix elements, ∞-norm [16] is the maximum values in each row sum,2- norm is the largest singular value of matrixare computed. The general equation to compute SD is given in Equation (1).

$$\mathrm{SD} = \sqrt[2]{\frac{1}{\mathrm{n}}\sum_{\mathrm{i}=1}^{\mathrm{n}}(\mathrm{Pi}-\mathrm{Pa})^2} \qquad (1)$$

where, Pi represents the current location of SD to be computed, 'n' is the total number of elements in the mask and Pa is the Mean of mask under consideration given by $=\frac{1}{n}\sum_{k=1}^{n} P_k$

Average 2 attributes are as in Table 1 are computed on the other wing of the algorithm. The Normalized Gray-Level Co-Occurrence Matrix (NGLCM) [17] features are derived which works on principle of frequency of occurrences of pairs. The entire image is normalized to selected gray level, suppose if the gray level is two, we get 2*2 matrix as the output. Each value of 2*2 matrix is a number obtained by computing the frequency of occurrence of pair pixel intensities in either directions. It is calculated for four different directions such as 0^0, 45^0, 90^0, and 135^0 and algebraically added. Only the intensity range of pixels between 100 and 200 are considered for the same.

Table 1: Features Extraction process on 5*5 Image sample.

5*5 Original Image					Matrix Rank					Trace	Standard Deviation	Inf. Norm	2 -norm	Aver age 1
231	193	131	209	231	5					745	59.33	995	884.17	537.7
242	131	168	140	248	**5*5 Peak to Peak Processed Image**					**Principal Diagonal Elements**	**Secondary Diagonal Elements**	**Dominant NLGCM features**	**Average 2**	
238	147	185	115	237	111	111	78	117	108	111	108	102	107	
247	173	141	130	227	111	111	94	133	133	111	133	21	88.33	
					116	116	70	133	133	70	70	16	52	
91	67	160	81	68	180	180	118	169	169	169	180	5	118	
					180	180	106	159	159	159	180	2	113.67	

Peak to peak mask processing on each preprocessed image pixel is calculated using the highest and lowest value of pixel intensities difference within 3*3 overlapping mask. One hundred significant values of NGLCM and diagonal values of Peak to peak mask processing along with matrix features obtained in previous wing are fused to get final features or attributes of each preprocessed image. The complete process of attributes generation is depicted in Table 1 for a 5*5 sample image.

4) Comparison of Attributes

The decision making step of recognition is performed in this section. The repository and test / probe image features are compared to get recognition output. Euclidean Distance (ED) measure is efficient to discriminate the distinct attributes of images. As the lowest ED value is decided as recognized. The general equation for ED computation is given in Equation (2), where *i* vary for all the elements of each vector and P,$Q$are any two vectors.

$$\mathrm{D(Pi, Qi)} = \sqrt{((\mathrm{p1} - \mathrm{q1})^2 + (\mathrm{p2} - \mathrm{q2})^2 + ..} \quad (2)$$

IV. ALGORITHM

The proposed RFRR algorithm is depicted as in Table 2 with the following objectives.

- To increase the % Recognition Rate (RR).
- To decrease error rates

Table 2: Proposed RFRR algorithm

Input: Repository of face Images
Output: Authenticate a person.

1. Preprocessing involves
   (i) Color to intensity optional conversion
   (ii) Roberts boundary detection
   (iii) Image Segmentation
   (iv) Uniformly resized to 50*50
2. Only probe / query inputs are rotated from 00 to +/-1500 angles
3. Each 50*50 size image is partitioned into 100 pieces with each part has 5*5 size
4. For each piece of 5*5, matrix rank, trace, Standard deviation, ∞ and 2-norm are computed.
5. One hundred coefficients per preprocessed image are extracted using matrix rank, trace, Standard deviation, ∞ and 2-norm.
6. The peak to peak processing using 3*3 non-overlapping mask for each image pixel (without preprocessing), is the difference between highest and lowest value is computed and resized to 100*100.
7. Both diagonal elements each of 100 from the output of step 6 are added with 100 NLGCM features 100 features, finally fused with output features of step 5 to get final features
8. Euclidean distance measure is used to match repository and test image attributes.
9. The recognized result is obtained for the image with minimum Euclidean distance.

V. RESULTS AND DISCUSSIONS

The proposed RFRR algorithm is applied on Kinect repository or database, which is publically available. It is also tested for the database created by us using fifty one persons with ten different samples of expressions and pose. The real time testing on created database is carried out to get convincing results. The robustness performance is observed for five trained images per person in two ways; i) By varying the count of known / repository / database persons inside and outside, ii) By varying the rotation angle with fixed threshold value. The success rate is measured in terms of % RR and the error rates are measured in terms of False Acceptance Ratio (FAR) and False Rejection Ratio (FRR). % RR indicates the recognition of right person correctly, where FRR represents the right person is not identified properly. Finally FAR depicts the unknown person recognized wrongly. The proposed algorithm is tested using 32 bit operating system, Intel (R), Pentium (R), CPU P2600 2.13 GHz processor with 4GB RAM on MATLAB 2013a version.

(i) By varying the count of known / repository / database persons inside and outside: As the Kinect repository consists of 52 subjects or persons and 50 persons of created database. The Persons Inside Repository (PIR) and Persons Outside Repository (POR) ratio is varied in steps for the fixed value of Threshold. The % RR, time elapsed for database and test feature set creation is recorded over different PIR: POR ratios. It is observed that the % RR and elapsed time increases with the increase of number of persons inside the database as in Table 3. It is recorded a lowest % RR of 95.23 with 8.28 and 3.73 seconds elapsed time respectively for database and test image features at 21:31, PIR:POR ratio. A highest % RR of 98 is obtained at 50:2, PIR: POR ratio with 18.69 and 3.81 seconds elapsed time respectively for database and test image features. Table 4 depicts highest % RR variation for different PIR:POR ratios. The plot for 50:2, PIR: POR ratio is in Figure 3, documents the variation of False Rejection Ratio (FRR) and False Acceptance Ratio (FAR), which are the error metrics in recognition process.

Table 3: Performance metrics over PIR: POR ratio variation on Kinect database

PIR:POR Ratio	Results for 0^0 Rotation with 0.1 Threshold		
	% RR	Time elapsed for Database in seconds	Time elapsed for Test data in seconds
21:31	95.23	8.28	3.73
22:30	95.45	8.51	3.72
25:27	96.00	9.55	3.74
30:22	96.67	11.66	3.80
35:17	97.14	13.12	3.88
40:12	97.50	15.03	3.79
45:7	97.78	16.98	3.80
48:4	97.91	17.76	3.80
50:2	98.00	18.69	3.81

Table 4: Recognition rate over PIR: POR ratio variation on created database

PIR:POR ratio	20:30	25:25	30:20	35:15
Highest % RR	90	92	93.33	91.42

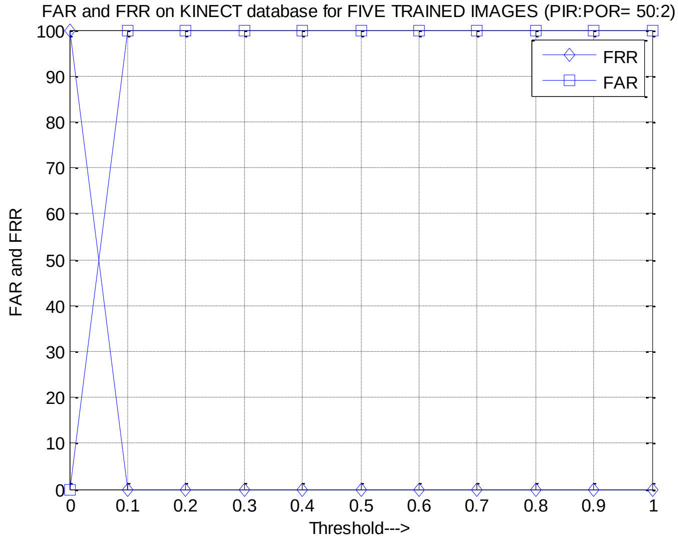


Figure 3: FAR and FRR variation with threshold for 50:2 PIR: POR ratio on Kinect database

(ii) By varying the rotation angle with fixed threshold value:

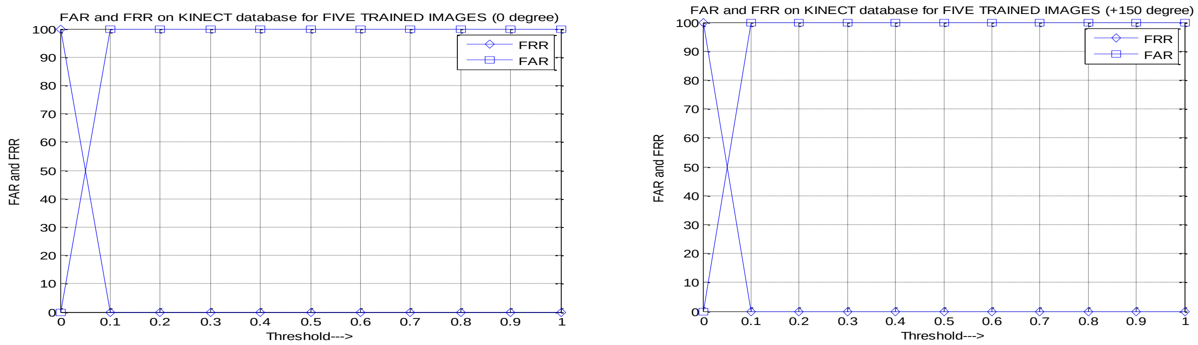
The proposed approach is tested for different rotation angles both in counter / anti clockwise (positive angles) and clockwise (negative angles) on Kinect database. The results computed for the 0.1 fixed value of Threshold with five trained images per person for 52 persons and 29:23, PIR: POR ratio. The rotation angles starts from 0^0 to + / - 150^0 in appropriate steps. The results obtained for counter / anti clockwise (positive angles) variation of rotation angles with % RR is as portrayed in Table 4. A highest % RR of 96.55 and lowest % RR of 3.44 is obtained respectively at 0^0 and + 150^0 rotation. Table 5 shows the clockwise rotation results on Kinect database. The variation of FRR and FAR with threshold for 0^0 and + 150^0 is shown in Figure 4 (a) and 4 (b) respectively. It exhibits robustness in maximum % RR for the rotation angles within three degrees of test image i.e. from -2^0 to +3^0as in Table 5 and 6.

Table 5: Counter / anti clockwise rotation results on Kinect database

Threshold	**% RR for different Rotation angles**								
	+ 0^0	**+ 4^0**	**+ 5^0**	**+8^0**	**+ 10^0**	**+ 25^0**	**+ 50^0**	**+ 100^0**	**+ 150^0**
0.1	96.5517	93.1034	89.6552	37.9310	27.5862	13.7931	10.3448	6.8966	3.4483

Table 6: Clockwise rotation results on Kinect database

Threshold	**% RR for different Rotation angles**								
	- 0^0	**- 3^0**	**- 5^0**	**- 8^0**	**- 10^0**	**- 25^0**	**- 50^0**	**- 100^0**	**- 150^0**
0.1	96.5517	93.1034	82.7586	44.8276	34.4828	6.8966	6.8966	6.8966	3.4483



(a) 0^0 Rotation **(b) + 150^0 Rotation**

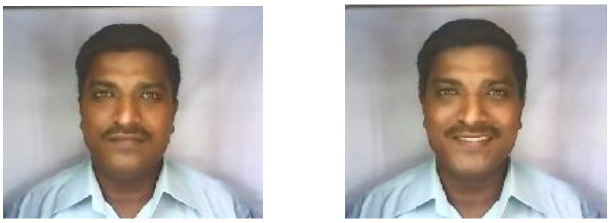
Figure 4: FAR and FRR variation with threshold for (a) 0^0 and (b) + 150^0 rotation

Table 7 compares the % RR of the proposed method with the other [18 - 22], methods. It is observed that the proposed algorithm achieve better results than the methods compared.

Table 7 : % RR Comparison

Database	Method	% RR
Kinect	HOG – 100 Samples Case [18]	86
	FR DMF model [19]	93.1
	FPLBP [20]	94.3
	SURF + k-NN with KD Tree [21]	95.51
	KNN +SVM: Kinect v2 [22]	95.19
	Proposed RFRR model	96.55

The proposed method is tested for real time recognition using HP - webcam 101 camera. Result is as shown in Figure 5.



(a) Recognized database image (b) Runtime captured image

Figure 5: Result of real time recognition

The obtained results are justified for following reasons: the Robert's edge / boundary detector used in preprocessing is elegant in eliciting fine details. The robustness is boosted through statistical yet substantial quality attributes such as matrix rank, trace, standard deviation, infinite and 2-norm in one wing of algorithm. On the other wing, the exclusive features extracted by NLGCM and peak to peak processing have contributed to improve the performance. Finally features fusion is acted as catalyst to get improvement in success of the recognition.

VI. CONCLUSION AND FUTURE WORK

The authentication of persons through faces is an eternal requirement in many applications including in academic campus, authenticated transactions etc. The Robert's edge operator is deployed in preprocessing to crop and refine the images. The approaches using statistical matrix features, NGLCM, Peak to peak processing are instrumental in developing the proposed model. One hundred fused attributes of repository and test / probe images are compared using Euclidean distance measure. The results are convincing over other approaches on the popular publically available Kinect face database.

In future, the proposed model can be extended for complex environments using videos over different practical challenges.

Data Availability Statement (DAS)

All authors assure that the data and materials that support the results or analyses presented in their paper freely available upon request.

Declarations

- All authors declare that they have no conflict of interest.
- Authors declare that no funding was received from any organization or agency

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