IEEE Access
Multidisciplinary | Rapid Review | Open Access Journal

Received February 17, 2019, accepted March 12, 2019, date of publication March 21, 2019, date of current version April 5, 2019.

Digital Object Identifier 10.1109/ACCESS.2019.2906033

UAV's Agricultural Image Segmentation Predicated by Clifford Geometric Algebra

PRINCE WAQAS KHAN[1,2], GUANGXIA XU[1], MUHAMMAD AHSAN LATIF[3], KHIZAR ABBAS[3], AND AMMARA YASIN[4]

[1]Chongqing Key Laboratory of Cyberspace and Information Security, Chongqing University of Posts and Telecommunications, Chongqing 400065, China
[2]School of Computer Science and Technology, Chongqing University of Posts and Telecommunications, Chongqing 400065, China
[3]Department of Computer Science, University of Agriculture Faisalabad, Faisalabad 38000, Pakistan
[4]Department of Mathematics and Statistics, University of Agriculture Faisalabad, Faisalabad 38000, Pakistan

Corresponding author: Guangxia Xu (xugx@cqupt.edu.cn)

This work was supported in part by the National Natural Science Foundation under Grant 61772099, in part by the Program for Innovation Team Building at Institutions of Higher Education in Chongqing under Grant CXTDG201602010, in part by the University Outstanding Achievements Transformation Funding Project of Chongqing under Grant KJZH17116, in part by the Artificial Intelligence Technology Innovation Important Subject Projects of Chongqing under Grant cstc2017rgzn-zdyf0140, in part by the Innovation and Entrepreneurship Demonstration Team Cultivation Plan of Chongqing under Grant cstc2017kjrc-cxcytd0063, in part by the China Postdoctoral Fund under Grant 2014M562282, in part by the Project Postdoctoral Supported in Chongqing under Grant Xm2014039, in part by the Wenfeng Leading Top Talent Project in CQUPT, in part by the New Research Area Development Programme under Grant A2015-44, in part by the Science and Technology Research Project of Chongqing Municipal Education Committee under Grant KJ1400422, Grant KJ1500441, Grant KJ1704089, and Grant KJ1704081, in part by the Chongqing Research Program of Basic Research and Frontier Technology under Grant cstc2017jcyjAX0270, Grant cstc2018jcyjA0672, and Grant cstc2017jcyjAX0071, and in part by the Industry Important Subject Projects of Chongqing under Grant CSTC2018JSZX - CYZTZX0178 and Grant CSTC2018JSZX - CYZTZX0185.

ABSTRACT Image segmentation is widely used in the field of agriculture to improve the yields and protecting them from pests, herbs, shrubs, and weeds. Precision agriculture is also contributing to the inter and intra crop monitoring. Recently, unmanned aerial vehicles are used widely for acquiring images. In this paper, we purpose Clifford geometric algebra to enhance the segmented images acquired from the UAVs of different agricultural fields. The Clifford geometric algebra is also sometimes used as a collective term for the diverse range of mathematical fields, both classical and modern algebraic mathematics. Previous image segmentation approaches depend upon the intensity of red, green, and blue colors; but the complete perspective could not be obtained from these approaches. Geometric algebra overcomes this limitation and leads to a genuine color space image processing. It is mainly used in the processing of medical images. Subalgebra of the Clifford algebra is Quaternions. We have used this approach in agricultural images. The image segmentation of foreground and background is enhanced using Clifford geometric algebra; hence, the results obtained are fine-tuned segmented images. The anticipated result of our research would have a positive impact on the amelioration of the condition of the farmers and their livelihood.

INDEX TERMS Clifford algebra, computer vision, geometric algebra, image processing, image segmentation, precision agriculture, UAV, unmanned aerial vehicles.

I. INTRODUCTION

This Innovative and ingenious technologies could have a distinctive transformational effect on forestall as well as direct assistance in the identification of the general, short and long trends of crop health. We can take remedial actions to improve the agricultural and therefore the societal wellbeing. The radical development of technologies in recent years gives helpful ways to humanity in several fields. UAVs and Robots are used in the monitoring and harvesting of crops to make human work easy and time-saving [1]. Image processing is one of the most innovative technologies which helps us to identify the minor changes and to detect the objects which are not clearly visible to the human eye. Machines with video and image defogging algorithms can see in poor visibility weather conditions such as foggy weather [2]. A fully focused image can be obtained using multi-focus image fusion by extracting sharp regions from different images [3]. The development of image processing can be used in the agriculture platform to improve crop yields and protect them from the problems

The associate editor coordinating the review of this manuscript and approving it for publication was Md. Asikuzzaman.

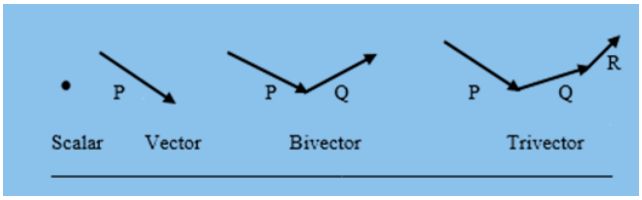

FIGURE 1. Scalar, vector and bivector and trivector.

of pests, herbs, shrubs and weeds. By yielding the healthy crops we can give nutritional food to humanity. The use of latest technologies could also result in maximizing the agricultural products, which will be helpful for both farmers and consumers. Clifford's geometric algebra has a deep application in different fields of artificial intelligence including Image processing, computer vision, robotic imaginative and prescient control problems. Recently, several fields have advanced based upon these technologies and mathematics but mostly over the past two decades. Clifford Algebra (CA) is a specialized mathematical study that employs extensively by researchers for more than a century. With the advent of computer technologies, its scope has become the more significant and powerful new computational tool in a diverse number of research fields. The subfield provides a mathematical naturalism to aspects of geometric objects unprejudiced of their coordinates with its effective and easy symbolic formalism. Geometric Algebra usage can even be speedier and more powerful than ordinary ones. We display a case on that it is so natural to depict calculations in Geometric Algebra and present our innovation for the coordination of Geometric Algebra into standard programming dialects. A quaternion is a scientific develop that comprises of four individual numeric parts. Quaternions are a helpful system for epitomizing introduction data since they require just four units of numeric stockpiling, rather than the nine required for a pivot network.

The numerical formalism of CA depicts geometry. while it permits us to manage direct subspaces speaking to geometric items, changes and relations between them in an exceptionally exquisite manner [4]. Its applications in the building are not simply restricted to the representation of geometric substances. But it is a vast extensive rundown of uses, i.e. projective invariants, various view geometry, mechanical autonomy, computer vision (camera adjustment, posture estimation, question acknowledgment) and vector machines, etc. A standout amongst the most intriguing elements of multivectors in GA is its organizational autonomy [5].

CA combines all the best thoughts from past work to accomplish a solitary steady formalism that sums up to self-assertive quantities of measurements. Clifford algebra characterized a progression of a compound number knows as ''cliffs'' or ''multi-vectors'' that range from zero measurements (scalar) to one measurement (vector), two measurements (bi-vector), three (tri-vector) and on upward to the extent you want to go. In CA measurements are alluded to as ''evaluations'', so a scalar is review zero and a vector is Grade 1.

CA is the most exceptional synergistic conversion of various scopes each with its own particular techniques and formalisms. All scopes locate a solitary bound together formalism under CA different than the standard vector examination whose primitives are scalars and vectors for speaking of different focuses and lines. CA has extra spatial primitives for speaking to plane and volume sections in two and three dimensions where it can be stretched out to any number of higher measurements by a similar essential plan. By adding one additional measurement to a sum of 4 delivers a projective geometry, give some wonderful invariance properties basically communicated in CA. similarly, by adding two extra measurements to an aggregate of 5, empowers a conformal geometry with considerably more remarkable invariances which are reminiscent of specific properties of observation. Conventional color image processing depends on marginal channel wise red, green and blue color processing. Thus, color space is not approached in a holistic 3D approach.

To overcome this problem, a new holistic multidimensional non-marginal treatment is introduced in quaternions and CA. it will also lead towards a color space in image processing, which will compare pictures and rotated relative to one another in color space. CA can be further used in artificial intelligence which is related to image processing. The implementation of geometric polynomial math can be highly helpful for separating the concerned versors which can incorporate rotors, interpreters and broadest movement. Many items (vectors, focuses, lines, circles, engines) can be used to one regular variable based math and improving programming executions. Direct administrators can be amplified by means of outer morphisms and prompting to minimal arrangements where both turn out to be richer than in proportional network theoretic definitions. CA scope is not confined to physics only. It covers scene analysis, optical positioning robotic and also for the camera localization of multiple cameras.

The scientific techniques of Image Segmentation involve in extracting the necessarily desired pixels from an image which could enhance images in terms of color, intensity, or texture. This involves diverse usage of innovative techniques e.g. edge detection, region-growing methods and clustering. The aspect of precision agriculture is also important for inter-crops and intra-crops monitoring which assists farmers to identify the changing health of crops, scientifically observe, measure and respond to crop variations. In the developing countries, this method could be extensively used to improve Agriculture which is the backbone of their economy. The traditional image segmentation is limited because of it dependents on the color intensification of the red, green and blue. Geometry and algebraic mathematical computation combination overcome this problematic by the possibilities of genuine color space image processing, fundamentally used in processing images in the agriculture field. In this paper, we study an agriculture platform and we propose a novel approach using Clifford geometric algebra on the image processing technique to enhance segmented agricultural images acquired from UAVs.

II. RELATED LITERATURE

Agriculture is a noteworthy wellspring of sustenance, fills, fiber and crude materials. This segment demands a quick change in its respect to satisfying the necessities of quickly expanding the populace. Agriculture area can play an important role in improving some fields such as organic products ranches and animals. There will be a need to encourage the populace of more prominent than 9 billion by the year 2050. To accomplish this objective there should be across the board and continuous interests in the human funding to improve the appropriation of new technologies [5]. Image segmentation should be possible to use in light of shading, contrast, or surface. Diverse techniques such as edge recognition, region-developing strategies and clustering are utilized for this purpose. Image processing is an immediate system for changing the photograph into its impelled shape with the genuine reason for enhancing its visual structure or removing some productive data from it. The entire idea of image processing with a combination of securing image information and video processing is to see several cases that are normally not clear to the human eye. It also gives a better overview of a photograph and recovering those parts of the photograph that is of intrigue by yielding the subsequent picture in the context of some image investigation. The basic idea for the segmentation in image preprocessing is isolating a piece of information from the picture into two or three territories with close properties such as shading, surface, control, etc. The pixels that offer a measure of fundamental visual qualities are stuffed into the same locales when showed up diversely in connection to the following pixels. Nowadays, image processing is a central research zone inside sketching out and programming planning orders. An expansive blend of computational vision issues could make mind-blowing utilization of segmented images.

Recently, radiologists work on the best way to deal with the implementation of radiation to a tumor while staying away from the basic parts of the body. To redesign the confirmation of heart problems, image examination strategy is applied to radiographic images. This image segmentation technique decreases the time required for radiation treatment arranging in a general sense. Color image segmentation is useful in different unmistakable applications. From the segmented image, it is effectively conceivable to see the required district of intrigue [12]. Image segmentation forms the basics of pattern recognition and scene analysis problems. The segmentation techniques are numerous in number but the choice of one technique over the other depends only on the application or requirements of the problem that is being considered. In Agriculture, UAVs are used in many areas like monitoring crops, cultivate arrangement, detecting water system channel, thermal imaging and herbicide safe weed mapping.

Geometric algebra (Clifford algebra) is a capable mathematical section for typical counts. It is related to many fields of research, for example, computer vision, CAD/CAM, mechanical autonomy, material science and any application in which the portrayal and manipulation of geometric elements are vital. As a bringing together numerical dialect, geometric algebra includes various scientific depictions generally utilized as a part of computer vision, for example, quaternions to speak to pivots and Lie algebras for inflexible body movement portrayals. Clifford algebras had been applied within the problem of movement reputation and class in computer vision.

A Clifford embedding to generalize conventional MACH filters to video (3D spatiotemporal extent) and vector-valued facts consisting of optical go with the flow. Vector-valued data has analyzed the use of the Clifford Fourier rework. Primarily based on those vectors movement filters are synthesized inside the Clifford Fourier domain and recognition of moves has finished the use of Clifford correlation. The authors [6]–[10] demonstrate the effectiveness of the Clifford embedding with the aid of spotting moves usually completed in conventional function films and sports broadcast TV.

Some of the significant work in the field of image processing while using Clifford algebra can be seen in [6] where the authors throw light on image compression based on block truncation coding. Reference [7] has performed segmentation of medical images and their volumetric representation while using the framework of geometric algebra. Reference [8] Used the same framework to model the 3D kinematics of the eye. Reference [9] Performed geometric pre-processing, geometric feedforward neural networks and Clifford support vector machines for visual learning. The representation of geometric objects and their transformation are the two key aspects in computer graphics applications. This was stated by [10] they explain the working of Field-programmable gate array -based computer graphics coprocessor with native geometric algebra support. Processing and neuro-computing for pattern recognition and pose estimation are also done through using geometric algebra framework [11]. Image Segmentation could be done on the basis of color, intensity, or texture. Different techniques are being used for this purpose. Edge detection, region-growing methods and clustering are the few common methods used for this purpose. The complete thought of image processing is to consolidate and secure the data picture by cutting edge photography, video layout, taking a gander at and moving the photo in order to perceive a couple of cases and yielding the output picture in perspective of some photo analysis [12].

The purpose of the segmentation in a picture is to involve dividing a data picture into a couple of ranges with near properties like shading, surface, power etc. Basically, radiologists investigate the most ideal approach to apply radiation to a tumor. To upgrade the assurance of heart problems, image examination methodology is used to radio-graphic pictures. This photo division method diminishes the time required for radiation treatment orchestrating fundamentally. Image contrast segmentation is in like manner supportive in various distinctive apps [6].

FIGURE 2. CA based image segmentation process and phases.

FIGURE 3. Original image acquired from UAV.

III. RESEARCH DESIGN

The three main stages in our research design are image acquisition, image segmentation and Clifford algebra technique quaternion operations.

A. DATA COLLECTION

The collection of the image data occurred under pleasant and clear weather conditions in the University of Agriculture Faisalabad crop fields. Different images were taken at different times but fig 3 is selected for the further tests. The original image was of a large size (i.e. 4000 × 3000 px) but we reduced the size maintaining its aspect ratio (1000 × 750 px). The image file size is 442307 bytes and format is jpg.

The study was conducted in the winter of 2017. Study Site is agricultural property owned by University of Agriculture Faisalabad, Pakistan.

B. IMAGE SEGMENTATION

Regardless of the possibility that two hues appear to be identical to one individual, slight contrasts might be discovered when assessed with a shading estimation instrument. If the color of a sample does not coordinate the standard, consumer loyalty is traded off.

L*a*b* color space was defined by CIE based on the color opponent theory which says that two color components cannot be green and red or blue and yellow at the same time. In this color space L* shoes luminous, a* represent the red and green coordinates and b* represent yellow and blue coordinates. The following formula is used for finding total color difference:

$$\Delta E* = [\Delta L * 2 + \Delta a * 2 + \Delta b * 2]1/2 \qquad (1)$$

The file size segmented image is 206853, format is jpg, resolution is 1000 × 750 and bit depth is 24.

FIGURE 4. Segmented image.

C. QUATERNION TEXTURE SEGMENTATION METHOD

The calculation for segmenting an image into districts of a homogenous color surface. The principal stage is to remove an orthogonal reason for the shading surfaces in an image. This premise is figured by inspecting pixels from the image and communicating the s of each such window as a vector of quaternions and masterminding these vectors as the segments of a grid. QPCA connected to this lattice yields an orthogonal reason for the s of the windows requested regarding the fluctuation represented by every premise vector. Like the standard PCA, the dimensionality of the element space can then be diminished by choosing just the initial couple of bases that record for most the fluctuation. These premise vectors will be vectors of quaternions. The scalar of any image window can then be approximated briefly by anticipating them onto the chose premise. The projection can then be utilized as the removed shading surface element of the window. The structure of the quaternion image contains 4 data members X, Y, Z and W. These data members are the (x, y, z) components of the imaginary vectors and W is the real-valued scalar of the quaternion.

D. RGB CONVERSION TO QUATERNION

The conversion of RGB image into quaternion use the function q which is equal to *quaternion (a0, a1, a2, a3)* [13]. We have three components i.e., R, G and B so we will get three pure quaternion matrix, with an empty scalar part. For example, we take the very first pixel of our image (1, 1) its RGB values are as follows 180, 183 and 166.The maximum value we have is 256 so we will divide each color matrix and pass then values to the quaternion function.

$$\begin{aligned} W &= 0 \text{ scalar part will be empty} \\ X &= R/256 = 0.7031 \\ Y &= G/256 = 0.148 \\ Z &= B/256 = 0.6484 \end{aligned}$$

E. QUATERNION MASK

A 3 × 3 mask is created and applied on the image on which to convert it into quaternion. It contains two parts. Left parts contain R in the first row and R* in the last row whereas in

the right part their positions are interchanged.

$$\begin{matrix} R & R & R \\ 0 & 0 & 0 \\ \bar{R} & \bar{R} & \bar{R} \end{matrix} \text{ x [] x } \begin{matrix} \bar{R} & \bar{R} & \bar{R} \\ 0 & 0 & 0 \\ R & R & R \end{matrix} \tag{2}$$

Refer to (2), $\bar{R}$ is the conjugate of R. The equation of R is as follow.

$$R : Se^{i\frac{\pi}{4}} = \mathrm{S}\{\cos\frac{\pi}{4} + \mu \sin\frac{\pi}{4}\} \tag{3}$$

Refer to (3), S denotes the scale factor SF which is used to addition of pixel from example to the addition of 6 pixels' in equation value of S becomes $1\sqrt{6}$. μ is pure quaternion unit.

$$\mu = \frac{(\mathrm{i} + \mathrm{j} + \mathrm{k})}{\sqrt{3}} \tag{4}$$

This mask operator of quaternion R [] R* defines how the rotation around axis P will be done by using angle $\pi/2$. This was discovered by Hamilton [14]. The conjugate of R will reverse the sense of rotation i.e., R*. In our case, Axis P is the grey line of RGB images that contains black to white pixels and all R, G and B pixels which falls in this range. The upper row of mask pair rotates the pixel values to the angles $+\pi/2$ and the lower row of mask do the same to the angles $-\pi/2$. If we talk about HSI coordinates, the rotation is the hue shift among the hue saturation and intensity. S is SF for the 1-pixel distance values, $\mathrm{S} = 1\sqrt{1}$.

In table I, the quaternion left mask value of R, are indicated. The w, x, y and z are the component of imaginary vectors.

TABLE 1. Values of R Scale Factor 1.

Quaternion Components	R Values
W	0.7071
X	0.4082
Y	0.4082
Z	0.4082

In table II, the quaternion right mask values for R* are indicated. The w, x, y and z are the component of imaginary vectors. R* is the conjugate of R.

TABLE 2. Values of R* Scale Factor 1.

Quaternion Components	R* Values
W	0.7071
X	-0.4082
Y	-0.4082
Z	-0.4082

The impact of mask with scale factor 1 is shown in Figures 6-8. A comparison of Red, Green and Blue channels is done before and after implanting the 3 × 3 Mask.

FIGURE 5. Output image with pixel distance 1.

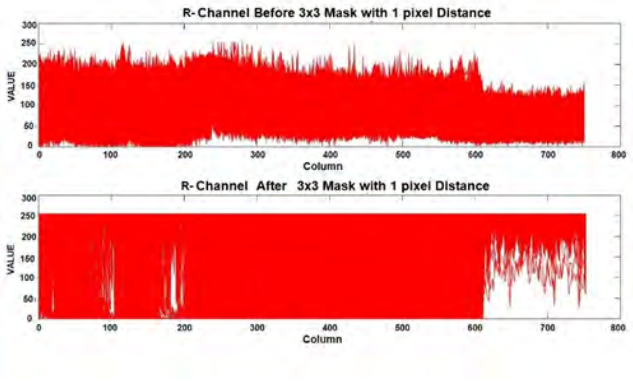

FIGURE 6. R channel before and after 3*3 mask with 1-pixel distance.

These graphs show the change in pixel values of these channels.

These graphs show that before applying mask 3*3 with 1-pixel distance, the pixel values of RGB channels are not along with the range. After applying the mask, the obtained values are in the range of 250 px.

By applying scale factor 2 in the same image with pixel distance 2. The final output image is shown in fig 9. The Value of S becomes $1\sqrt{2}$.

For the verification of robustness of the proposed method some images are analyzed with different natural lighting conditions. We captured images under sunny weather, partial sunny weather and cloudy weather. We cannot use UAV in the rainy weather that is why we could not take the picture under the rain. In the windy conditions, it is difficult for UAV to fly and control so that the weather is ignored as well. Images taken in the daytime with clear sunlight have rich information as compared to images captured in partial sunlight. After applying the purposed methodology on these images we get the observation that this methodology gives good results in different natural lighting conditions. The output of these images after applying different scale factors are shown in fig 14.

IV. RESULTS AND DISCUSSION

With the improvements in economically advanced cameras, every single procured image is chromatic. In the meantime,

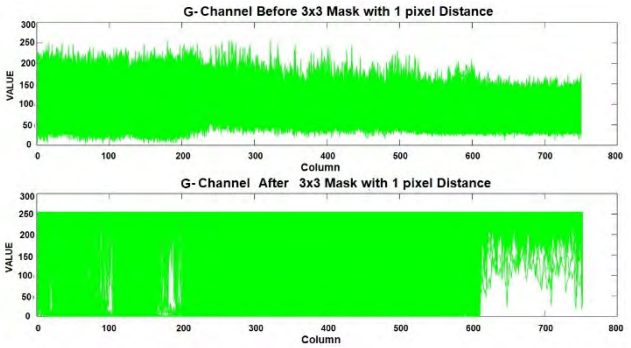

FIGURE 7. G channel before and after 3*3 mask with 1-pixel distance.

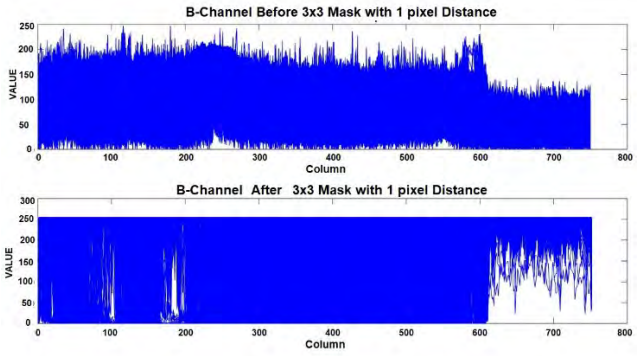

FIGURE 8. B channel before and after 3*3 mask with 1-pixel distance.

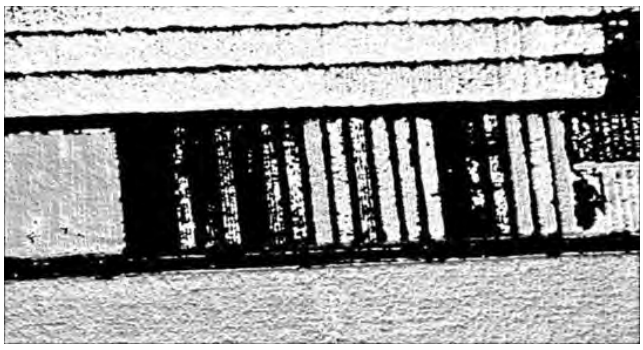

FIGURE 9. Output with pixel distance 2, Mask = 3 × 3 – Scale Factor = 2 and S = 1$\sqrt{2}$.

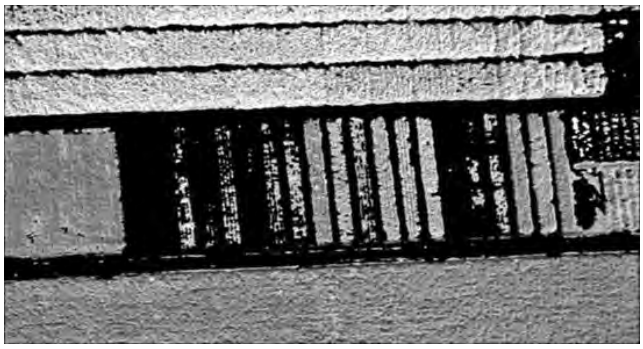

FIGURE 10. Output with pixel distance 3, Mask = 3 × 3 – Scale Factor = 3 and S = 1$\sqrt{3}$.

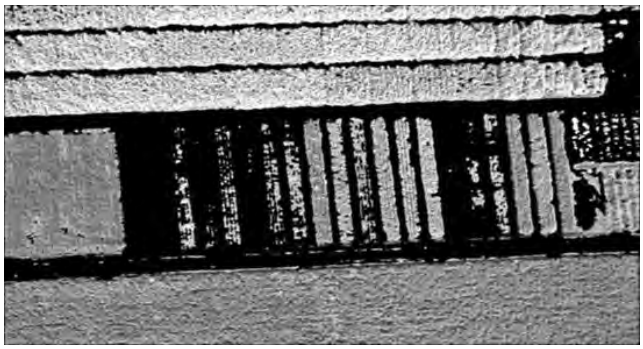

FIGURE 11. Output with pixel distance 4, Mask = 3 × 3 – Scale Factor = 4 and S = 1$\sqrt{4}$.

FIGURE 12. Output with pixel distance 5, Mask = 3 × 3 – Scale Factor = 5 and S = 1$\sqrt{5}$.

a color image can possibly pass on more data than a monochrome or a grey scale image. Different Image quality assessment (IQA) models are present to predict the quality of images [15]. The three values of red, green and blue (RGB) are related to every pixel or also its shine, tone and immersion can be effectively utilized in numerous computer vision assignments. The ordinary way to deal with the management of color images comprises in processing each channel independently, utilizing dim level procedures and to consolidate the individual yield comes about. In this manner, this approach neglects to catch the natural relationship between shading channels and the whole of three channels.

The primary goal is to deal with three estimations of every pixel in a comprehensive way. Recently, quaternions have been increasingly utilized as a part of shading image processing to speak to shading images by encoding three channels into the fanciful parts of quaternion numbers. The principal preferred standpoint of this quaternion portrayal is that a shading image can be dealt with comprehensively as a vector field. Many Classical approaches have been effectively stretched out to color image processing utilizing the quaternion algebra. The Clifford algebra which is speculation of quaternion algebra has been accounted for in the writing permitting the processing of higher dimensional signs like 3D

FIGURE 13. Output with pixel distance 6, Mask = 3 × 3 – Scale Factor = 6 and S = 1√6.

color images [16]–[20]. In this paper, we concentrate on the utilization of the quaternion algebra to extend the color image processing.

A. 3×3 QUATERNION MASK COMPARISON WITH DIFFERENT SCALE FACTORS

Here is the comparison of the effect of the quaternion mask on different pixels of the image. By using the CA technique Quaternion Mask 3 *3 we obtain values within the range of 0 to 1 and pixel intensity are decreased gradually. We select three test pixels (1, 1), (750 × 1000) and (752 × 1002). The experimental results of these pixels are shown in table 3.

B. COMPARISON OF GRAYSCALE IMAGE WITH QUATERNION MASK IMAGE

The most widely recognized technique to change over RGB pictures to grayscale is by disposing of the tint and immersion data while holding the luminance. In this strategy, we take an RGB picture and afterward change over it to grayscale by computing coefficients of luminance. We change over RGB esteems to grayscale values by framing a weighted aggregate of the R, G and B segments:

$$0.2989^{*}\mathrm{R} + 0.5870^{*}\mathrm{G} + 0.1140^{*}\mathrm{B} \tag{5}$$

The coefficient is similar for estimating grayscale values and luminance values Ey. The following formula is used to

TABLE 3. Comparison results of different scale factors on test pixels.

Quaternion Components	Scale Factors (SF) Output					
(1,1) Pixel (px)	**SF 1**	**SF 2**	**SF 3**	**SF 4**	**SF 5**	**SF 6**
X	0.1114	0.1337	0.1672	0.2229	0.3343	0.6686
Y	0.1182	0.1419	0.1773	0.2365	0.3547	0.7094
Z	0.1194	0.1432	0.1790	0.2387	0.3581	0.7162
(750,1000) px	**SF 1**	**SF 2**	**SF 3**	**SF 4**	**SF 5**	**SF 6**
X	0.1713	0.2056	0.2570	0.3427	0.5140	1.0281
Y	0.1729	0.2074	0.2593	0.3457	0.5186	1.0371
Z	0.1676	0.2011	0.2514	0.3351	0.5027	1.0054
(752,1002) px	**SF 1**	**SF 2**	**SF 3**	**SF 4**	**SF 5**	**SF 6**
X	0.0517	0.0621	0.0776	0.1035	0.1552	0.3104
Y	0.0317	0.0381	0.0476	0.0635	0.0952	0.1904
Z	0.0355	0.0426	0.0533	0.0710	0.1065	0.2130

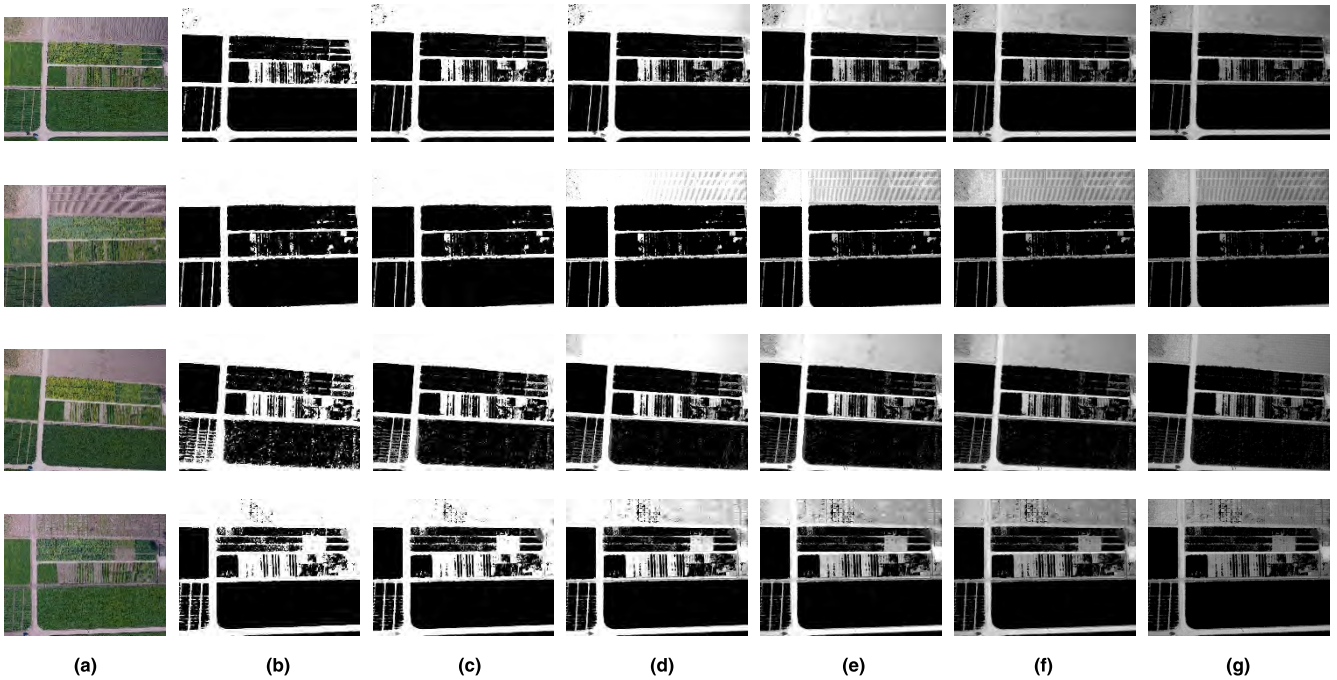

FIGURE 14. Outputs under different natural lighting conditions. (a) Original Image, (b) Scale Factor = 1, (c) Scale Factor = 2, (d) Scale Factor = 3, (e) Scale Factor = 4, (f) Scale Factor = 5, (g) Scale Factor = 6.

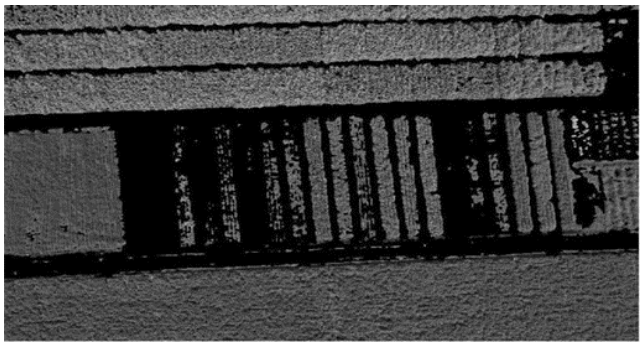

FIGURE 15. Output grayscale image with luminance coefficient.

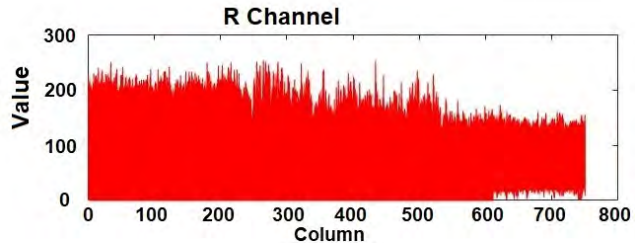

FIGURE 16. R channel values of gray scale image.

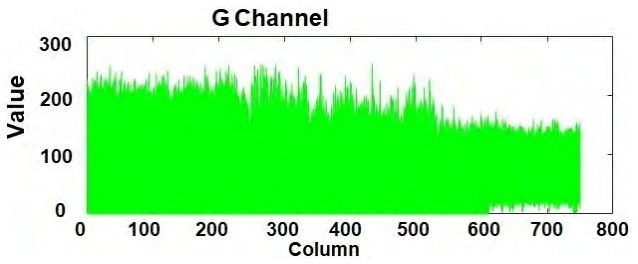

FIGURE 17. G channel values of gray sale image.

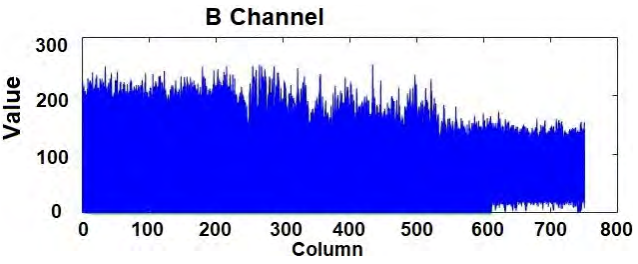

FIGURE 18. B channel values of grayscale image.

calculate Ey in Rec.ITU-R BT.601-7 [21].

$$0.299^{*}\mathrm{R} + 0.587^{*}\mathrm{G} + 0.114^{*}\mathrm{B} \tag{6}$$

Although we get an image of low intensity by using this method but the output image is full of noise. Hence, we cannot extract any useful information from this. If we make the plot of intensity values of RGB channels, then we get to know that the ranges which are not fixed in the original image. On the other hand, in the quaternion image, we get the color channels within the specific ranges. the above graphs RGB channels indicate that the values are not in the proper range like the original RGB image. By the quaternion mask, we obtain low-intensity pixel values which can be easy to interpret the information from the pixel values. In other words, the quaternion mask method of CA is better than the luminance technique for image segmentation and enhancement.

V. CONCLUSION

Clifford algebra gives a particularly gainful framework to make counts with the problems of image processing. These frames used in the turn-off internal, wedge and geometric objects and furthermore in the related geometric interpretations required in these operations [22], [23]. The securing space of the image is introduced into CA. The output images of very low-intensity values increase the processing time and efficiency. We use this algorithm in precision agriculture, where we have drones and site-specific crop management systems. Complex algebra based math and complex analysis are intense tools for taking care of issues in 2D spaces. The spurs researchers create techniques considering complex algebra to manage in 3D spaces. CA provides a complete solution to counter with the problems of multidimensional in image processing. We measure the assortments of the estimations of the pixels, seen as number motivations behind the space of the image, using geometric information and changes. We also obtain the metric data of the image surface required for edge detection. It can be used to measure soil and crop variability and characteristics. It will make farming more accurate and controlled. It will help farmers and soils work better, not harder. In the future, it could be enhanced to obtain the low intensity 3D models of agricultural lands as well.

ACKNOWLEDGMENT

The authors would like to show their gratitude to Dr. Stephen J. Sangwine from School of Computer Science and Electronic Engineering, University of Essex, United Kingdom, for his cooperation in this research.

REFERENCES

[1] R. Fernández, H. Montes, J. Surdilovic, D. Surdilovic, P. Gonzalez-De-Santos, and M. Armada, "Automatic detection of field-grown cucumbers for robotic harvesting," *IEEE Access*, vol. 6, pp. 35512–35527, 2018.

[2] Y. Xu, J. Wen, L. Fei, and Z. Zhang, "Review of video and image defogging algorithms and related studies on image restoration and enhancement," *IEEE Access*, vol. 4, pp. 165–188, 2016.

[3] X. Bai, M. Liu, Z. Chen, P. Wang, and Y. Zhang, "Multi-focus image fusion through gradient-based decision map construction and mathematical morphology," *IEEE Access*, vol. 4, pp. 4749–4760, 2016.

[4] W. E. Baylis, *Clifford (Geometric) Algebras: With Applications to Physics, Mathematics, and Engineering*. Springer Science & Business Media, 2012.

[5] R. Machucho-Cadena, J. Rivera-Rovelo, and E. Bayro-Corrochano, "Geometric techniques for 3D tracking of ultrasound sensor, tumor segmentation in ultrasound images, and 3D reconstruction," *Pattern Recognit.*, vol. 47, pp. 1968–1987, May 2014.

[6] K. Sau, R. K. Basak, and A. Chanda, "Image compression based on block truncation coding using clifford algebra," *Procedia Technol.*, vol. 10, pp. 699–706, 2013.

[7] R.-R. Jorge and B.-C. Eduardo, "Medical image segmentation, volume representation and registration using spheres in the geometric algebra framework," *Pattern Recognit.*, vol. 40, pp. 171–188, Jan. 2007.
[8] E. Bayro-Corrochano and R. Vallejo, "Geometric preprocessing and neurocomputing for pattern recognition and pose estimation," *Pattern Recognit.*, vol. 36, pp. 2909–2926, Dec. 2003.
[9] E. Bayro-Corrochano, R. Vallejo, and N. Arana-Daniel, "Geometric preprocessing, geometric feedforward neural networks and Clifford support vector machines for visual learning," *Neurocomputing*, vol. 67, no. 1, pp. 54–105, 2005.
[10] S. Franchini, A. Gentile, F. Sorbello, G. Vassallo, and S. Vitabile, "An embedded, FPGA-based computer graphics coprocessor with native geometric algebra support," *Integration*, vol. 42, pp. 346–355, Jun. 2009.
[11] E. J. Bayro-Corrochano, "Geometric neural computing," *IEEE Trans. Neural Netw.*, vol. 12, no. 5, pp. 968–986, Sep. 2001.
[12] N. R. Nayak, B. K. Mishra, A. K. Rath, and S. Swain, "Improving the efficiency of color image segmentation using an enhanced clustering methodology," in *Biometrics: Concepts, Methodologies, Tools, and Applications*. Philadelphia, PA, USA: IGI Global, 2017, pp. 1788–1802.
[13] S. J. Sangwine and E. Hitzer, "Clifford multivector toolbox (for MATLAB)," *Adv. Appl. Clifford Algebras*, vol. 27, no. 1, pp. 539–558, 2017.
[14] W. R. Hamilton, *Elements of Quaternions*. Harlow, U.K.: Longmans, 1866.
[15] D. Liu, F. Li, and H. Song, "Image quality assessment using regularity of color distribution," *IEEE Access*, vol. 4, pp. 4478–4483, 2016.
[16] T. Batard and M. Berthier, "Clifford algebra bundles to multidimensional image segmentation," *Adv. Appl. Clifford Algebras*, vol. 20, pp. 489–516, Oct. 2010.
[17] J. Zhu and J. Sun, "Global exponential stability of Clifford-valued recurrent neural networks," *Neurocomputing*, vol. 173, pp. 685–689, Jan. 2016.
[18] L. Yuan, Z. Yu, W. Luo, L. Yi, and Y. Hu, "Pattern forced geophysical vector field segmentation based on Clifford FFT," *Comput. Geosci.*, vol. 60, pp. 63–69, Oct. 2013.
[19] E. Bayro-Corrochano, "Modeling the 3D kinematics of the eye in the geometric algebra framework," *Pattern Recognit.*, vol. 36, pp. 2993–3012, Dec. 2003.
[20] E. Bayro-Corrochano and B. Rosenhahn, "A geometric approach for the analysis and computation of the intrinsic camera parameters," *Pattern Recognit.*, vol. 35, no. 1, pp. 169–186, 2002.
[21] *Studio Encoding Parameters of Digital Television for Standard 4:3 and Wide Screen 16:9 Aspect Ratios*, document ITU-R BT.601 1995.
[22] M. Shen, R. Wang, and W. Cao, "Joint sparse representation model for multi-channel image based on reduced geometric algebra," *IEEE Access*, vol. 6, pp. 24213–24223, 2018.
[23] J. Angulo, "Geometric algebra colour image representations and derived total orderings for morphological operators—Part I: Colour quaternions," *J. Vis. Commun. Image Represent.*, vol. 21, pp. 33–48, Jan. 2010.

PRINCE WAQAS KHAN received the M.Sc. and M.S. degrees in computer science from the University of Agriculture Faisalabad, Pakistan, in 2014 and 2017, respectively, where he worked as a Web Developer, from 2015 to 2018. He is currently pursuing the Ph.D. degree in computer science with the Chongqing University of Posts and Telecommunications, China. His research interests include artificial intelligence, image processing, the IoT, blockchain, and data mining.

GUANGXIA XU received the M.S. and Ph.D. degrees in computer science from Chongqing University, Chongqing, China. She is currently a Professor with the Chongqing University of Posts and Telecommunications, Chongqing, and also the Research Vice-Director of the Network and Information Security Engineering Center, Chongqing. Her current research interests include information security and network management, big data analytics for network security, and the Internet of Things data streams analytics. She is a committee member of the Fault Tolerant Computing of the China Computer Federation and the Vice Chairman of the Information Security Association, Chongqing.

MUHAMMAD AHSAN LATIF received the Ph.D. degree in computer science from Alpen-Adria University, Klagenfurt, Austria, in 2011. He is currently serving as an Assistant Professor with the Department of Computer Science, University of Agriculture Faisalabad, Pakistan. His main research interests include modeling, image processing, computer vision, and artificial intelligence in the agricultural context. Among his contributions are research articles, book chapters, a complete book on digital image processing, and various research projects. He is currently leading a research group aiming to map crop health under different nonlinear conditions using unmanned aerial systems and vision sensors.

KHIZAR ABBAS received the software engineering degree from GC University Faisalabad, Pakistan, in 2014, and the M.S. degree in computer science from the University of Agriculture Faisalabad, Pakistan, in 2017. He is currently a Research Scholar with Jeju National University, Jeju, South Korea. His research interests include software engineering, artificial intelligence, machine learning, image processing, and software-defined networks (SDN).

AMMARA YASIN received the master's degree from International Islamic University Islamabad, Pakistan, in 2013. She is currently a Lecturer with the University of Agriculture Faisalabad, Pakistan. Her research interests include Clifford algebra, wavelets, integral equations, and sparse matrices.