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RESEARCH ARTICLE

Analysis on application of swarm-based techniques in processing remote sensed data

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Abstract
The remote sensed satellite images are big repository of information and provide the coverage of large areas. However, these images may not be able to describe the finer details of area being covered. Satellite Image optimization is the process of augmenting the components of an image for better and effective interpretations from satellite images. In order to obtain better visibility properties to fetch more information, various artificial intelligence techniques can be considered for the optimization process. Finding out the best technique for optimization is a challenging and time-consuming task [U1]. In this paper, applications of swarm-based artificial intelligence techniques such as ant colony optimization, particle swarm optimization, bat algorithm, artificial bee colony algorithm etc. are being analysed to process the remote sensed data. The detailed comparison with respect to classifier, utility, images considered, and observation are discussed. The comprehensive analysis revealed that particle swarm optimization is the most widely used technique. Further, various application areas such as land-use land-cover are discussed with possibilities of future research [U2].

Keywords Satellite images · Artificial intelligence (AI) · Swarm intelligence · Image processing · Remote sensing · Optimization · Change detection · Classification · Land-use land-cover · Segmentation · Particle swarm optimization (PSO) [U3]

Introduction

Image Processing is one of the major fields of signal processing. In order to augment the worth of an image or to draw worthwhile information from an image, the images need to be manipulated using various image processing techniques (Jain 1989). With the help of digitization, an image is converted into a suitable form to store on a computer device. The fundamental requirements are that, image must be sampled and quantized. Once the image has been stored, image processing operations may be executed on the acquired image to get better and flawless information. Typical stages in image processing are acquisition and enhancement of an image. These techniques are used to carry out the restoration, segmentation (Zaitoun and Aqel 2015), object recognition, improvement in interpretability (Gajdhane and Deshpande 2014), better representation and description (Demirel et al. 2009) of an image [U4]. Image acquisition involves various pre-processing tasks such as histogram equalization, scaling, brightness control etc. These tasks are required for improvement of image data to suppress unwanted distortions for further processing. The image enhancement and restoration techniques primarily focus on refinements to control the appearance of an image (Demirel et al. 2009). The process of segregating an image into various sub-parts is known as image segmentation (Zaitoun and Aqel 2015). The image segmentation technique includes the partitioning of an image into subparts or objects and is a key step from image processing to image analysis. Recognition methods utilize the difference of grey values of an image (Lee et al. 1994). The image description provides the extraction of features to result in some quantifiable information of interest for segregating one class of objects from another class. The initial

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applications of image processing were majorly focused in the areas of news-paper and allied industries. With further advancements in technology, the application areas of image processing technology have increased to diversified fields such as medical imaging, Pattern recognition, robot vision and remote sensing imagery [U5].

The need for accurate, fast and cost-effective geospatial information provided by remote sensing technology is increasing day by day (Mohammadzadeh et al. 2009). The remote sensing technique contributes to take important decisions by providing the accurate information for a large area (Campbell and Wynne 2011). Many image processing and analysis techniques have been developed to aid the interpretation of remotely sensed images and to extract as much information as possible from the images. As the manual extraction and analysis techniques tend to be expensive with respect to efforts required, time consumed and quality. Therefore, there is a requirement for automatic image feature extraction technique to expedite the process, and thereby considerably reducing the cost, computation time and better interpretation of information from satellite images (Mohammadzadeh et al. 2009). Artificial intelligence (AI) may replicate the human intelligence model or some natural phenomena and is considered to be a part of machine learning (Alpaydin (2009). The conept of artificial intelligence has been introduced to develop human intelligence in machines (McCorduch 1979). AI is able to provide more precision with higher degree of accuracy. Enhanced capabilties for the spatial databases may also be developed with the help of AI (McKeown 1987). In AI, nature or bio inspired meta-heuristics algorithms models their behaviour upon the naturally occuring phenomena and are developed for optimization problems to provide sufficiently good results and makes sure that the computation or size are not increasing (Singh et al. 2017). AI based techniques are capable of improving the image analysis, to give precise information regarding geographic conditions and earth resources applications (Estes et al. 1986). Thus, the artificial intelligence techniques viz.- Genetic Algorithm, Particle Swarm Optimization, Cuckoo Search etc. may play a vital role to improve the quality and interpretation process of available satellite images. These techniques may be efficiently utilized to carry out various image processing operations such as image enhancement, segmentation, contrast variation, noise removal etc. [U6].

In satellite images due to huge data size, large time is consumed to interpret the correct information. Further, the quality of satellite images is affected by weather conditions. In order to reveal the finer information and to improve the visibility qualities of satellite images, there is a need for implementation of suitable artificial intelligence technique. This paper presents detailed comparisons of various swarm intelligence-based techniques such as ant colony optimization, artificial bee colony algorithm, particle swarm optimization, bat algorithm etc. with respect to classifier, utility, images used, observations including the advantages/disadvantages and comparisons [U7]. Further, applications, advantages and disadvantages of various swarm-based techniques in numerous areas of satellite images processing have been presented. The particle swarm optimization is one of the most widely used technique, further its application areas with future research scope have been discussed [U8]. The section 2 consists of literature review on implementation of swarm intelligence in satellite imagery. Section 3 consists of discussion drawn from section 2. The last section discusses the conclusion.

Remote sensing imagery

Remote Satellite Images are like reservoir of useful and interesting information. From these images, one can find out transformations of cities, crop classification and cultivation pattern, and damage assessment in case of natural calamities such as floods, fire, storms. Satellite images act like a rich repository of information related to agricultural activities. The focus on vegetation helps in understanding the crop growth from planting to harvest along with the observation of abnormalities and the change due to season progression (Senthilnath et al. 2008). Classification in remote sensing images is also a very crucial activity and is frequently carried out for obtaining the information related to land-use land-cover. Environmental changes at global, regional and local level can also be monitored closely with the help of land-use land-cover and the changes occurring over time (Turner et al. (1994) [U9]. Visible, Infrared and Water Vapor Imagery are the three important classifications of satellite images. Sunlight disseminated by objects suspended in the air or on Earth represents Visible Imagery. Infrared Imagery identifies the clouds by measuring the heat radiation using satellite sensors. Measurement of moisture in the upper atmosphere represents Water Vapor Image. Satellite image optimization with respect to registration, enhancement, classification and segmentation is achieved by various techniques such as discrete wavelet transformation, swarm intelligence, fuzzy logic, singular wave decomposition etc.

Swarm intelligence

Swarm Intelligence is an imperative concept in Artificial Intelligence with primary aim of performance optimization and robustness. Swarm intelligence is a bottom-up approach and behaves like a multi-agent system, where there are plentiful simple beings such as birds, fish, ants etc., and these beings work in full cooperation and competition among the individuals (Liu et al. 2008b) [U10]. Collective behavior emerged from social insects' forms swarm intelligence in which social exchanges amongst the individual representative help in finding out the optimal solutions for NP-hard problems. Different sorts of swarm optimization which are being utilized for streamlining are Artificial Bee Colony, Particle Swarm Optimization, Firefly Algorithm, Ant Colony, Bat Algorithm and so on. Swarm intelligence has been successful in solving complex problems such as network routing, pattern recognition, travelling salesman problems, data clustering and is currently a hot research topic in artificial intelligence (Liu et al. 2008b). Classification and feature extraction research based on swarm intelligence indicates that the new clasiification and intelligence computation methods helps in avoiding the imapct on classified results generated by artificial fault or deviation, improves the clasification validity and humanity and in reforming the robustness of the algorithm to operation management (Dong and Xiang-bin 2008).[U11].

Literature review

Optimization of satellite images in terms of enhancement, segmentation, classification, clustering is accomplished by actualizing swarm intelligence methods such as Ant Colony, Particle Swarm Optimization, Cuckoo Search and so on. The following section covers the review of application of various swarm intelligence algorithms. The major advancements in the area of swarm intelligence techniques initiated from the year 2006 onwards; this study considers the period from 2006 to 2018 and is divided into four sub-sections. The strings such as swarm intelligence in remote sensing, artificial intelligence in remote sensing and nature inspired algorithms have been used with prime consideration of remote sensing images. [U12].

Analysis from 2006 to 2008

Das et al. (2006) presented a hybrid framework comprising Particle Swarm Intelligence (PSO) and Rough-Set theory for image clustering. Zhong et al. (2006) worked in the area of classification of remote sensed data by the application of an innovative approach using Unsupervised Artificial Immune Classifier. In the first step, the clustering centres were randomly carefully chosen from the input images and later the classification task was carried out. Omkar et al. (2007) implemented Ant Colony Optimization and Particle Swarm Optimization for satellite image classification problem of land cover mapping. Monteiro and Kosugi (2007) presented a feature selection algorithm for remote data by implementing Particle Swarm Optimization (PSO). The method utilized swarm implementation for optimizing desired performance criteria and the count of selected features simultaneously. Senthilnath et al. (2008) implemented Particle Swarm Optimization, Maximum Likelihood Classifier (MLC) and Ant Colony Optimization in the area of crop coverage classification using high resolution satellite images. Liu et al. (2008a) have proposed the use of Ant Colony Optimization (ACO) for improving the classification performance. It was detected that the ACO algorithm gives better accuracy and rule set as compared to See 5.0 Decision Tree process. Liu et al. (2008b) proposed a new method using Particle Swarm Optimization (PSO) for satellite image classification. PSO is capable of finding optimized cut points and has good convergence in the exploration process. Dong and Xiang-bin (2008) worked in the area of image classification of remote sensed data showing the application of Particle Swarm Optimization. The advantage of neighbourhood information is utilized by PSO and is also a robust approach and can be implemented for other kinds of image classification. The detailed comparison is summarized in Table 1.

Analysis from 2009 to 2011

Mohammadzadeh et al. (2009) applied Particle Swarm Optimization (PSO) to a mean calculation system using fuzzy, for obtaining road mean value in each band. Maulik and Saha (2009) worked in the area of image classification and proposed a modified Differential Evolution (DE) using fuzzy clustering technique and also performed statistical significance tests for establishing the superiority. Chen and Leou (2009) have used Particle Swarm Optimization (PSO) for proposing a new IKONOS imagery fusion technique for Panchromatic (PAN) and Multispectral (MS) satellite images. The visual quality and correlation coefficients were better and greater than the other methods. Juneja et al. (2009) implemented and performed relative analysis of Artificial Neural Network (ANN), Rough-Set and Fuzzy-Rough classifier. Paoli et al. (2009) proposed unsupervised classification for hyperspectral images using swarm intelligence which optimized the Bhattacharyya statistical distance between classes and the log likelihood function.

Daamouche and Melgani (2009) implemented a novel classification scheme for hyperspectral images articulating wavelet optimization within Particle Swarm Optimization structure. Chang et al. (2009) worked in the area of hyperspectral image band selection by developing Greedy Modular Eigenspaces (GME) and a novel Parallel Particle Swarm Optimization (PPSO) was offered. The proposed technique improved the computational speed with the help of parallel computing techniques and better reliable solutions as compared to GME. Ding and Chen (2009) has proposed the use of Particle Swarm Optimization (PSO) for improving the Support Vector Machine (SVM) classifier performance for hyperspectral classification. It was observed that the SVM approach has superiority over other traditional classifiers.

Papa et al. (2010) implemented a hybrid Particle Swarm Optimization- Projections Onto Convex Sets (PSO-POCS) algorithm for remote sensing image restoration. Bedawi and Kamel (2010) proposed clustering algorithm using Particle Swarm Optimization (PSO) for segmentation of high

Table 1 Comparative analysis from 2006 to 2008

Reference	Assigned Number	Classifier	Utility	Images Considered	Observation
(Das et al. 2006)	1	PSO - Rough c-means algorithm	Image Segmentation	IRS image of Mumbai and the Nomadic Super Scout II Robot	Fitness function considered by the author is Davies-Bouldin clustering validity index. Even in the existence of noise, correct segments were recognized in the image.
(Zhong et al. 2006)	2	Unsupervised Artificial Immune Classifier	Image Classification	Multispectral Landsat TM image, MODIS image, PHI image	The classification results were compared with Fuzzy k-means, ISODATA, Self-Organizing Map and K-means. Better technique as compared to other four approaches
(Omkar et al. 2007)	3	Ant Colony Optimization and Particle Swarm Optimization	Image Classification	Quick-bird high resolution images	PSO is more efficient and introduces robustness as compared to Ant-miner. Both the techniques produce promising results
(Monteiro and Kosugi 2007)	4	Particle Swarm Optimization –Continuous and Binary	Feature Selection	Hyperspectral Datasets from Soybean Fields.	Superior performance in comparison with Principle Component Analysis
(Senthilnath et al. 2008)	5	Ant Colony Optimization, Maximum Likelihood Classifier and Particle Swarm Optimization and	Crop Coverage Identification Problem	Quick-Birds Multi-Spectral (MSS) image	Comparison of MLPNN trained by PSO, MLC and Ant Miner with respect to crop coverage identification
(Liu et al. 2008a)	6	Ant Colony Optimization	Improve the Classification Performance	Landsat TM image	Improved accuracy over See 5.0 Decision Tree Method and simple rule sets was obtained for Guangzhou area of study
(Liu et al. 2008b)	7	Particle Swarm Optimization-Miner Method	Image Classification	Landsat TM image	Panyu district of Guangzhou was considered. Better accuracy was observed than the See 5.0 Decision Tree Process.
(Dong and Xiang-bin 2008)	8	Particle Swarm Classifying Optimization Algorithm	Images Classification	Remote sensing images- Jidi area	The advantage of neighborhood information is utilized by PSO and is also a robust approach and has better universal compatibility

resolution images and the output was matched with K-means. Linyi and Deren (2010) worked in the areas of image fuzzy classification by proposing the use of Particle Swarm Optimization (PSO) and evaluation was done with Genetic Algorithm (GA) and mean value method. Ari and Aksoy (2010) worked for estimation of likelihood of Gaussian Mixture Models by presenting a Particle Swarm Optimization (PSO) based method. New parameterization for random covariance matrices was also presented. Gupta et al. (2011) proposed an extension of Biogeography Based-Optimization (BBO) for image classification. The migration rate is determined by using Rank based fitness criteria. Very accurate land-cover features were extracted.

Halder et al. (2011) presented supervised and unsupervised Ant based classification and clustering methods for automatic generation of landuse map. Senthilnath et al. (2011b) applied a novel Glowworm Swarm Optimization clustering method in image classification for multispectral satellite images. Goel et al. (2011) presented an innovative Particle Swarm Optimization - Biogeography Based Optimization (PSO-BBO) hybrid approach for classification of multispectral remote images. The method is very efficient and accurate in terms of land cover feature extraction. Arora et al. (2011) has proposed the application of Particle Swarm Optimization (PSO) with morphological operators in the classification of urban features in the satellite images. Samadzadegan and Mahmoudi (2011) proposed the implementation of Firefly Algorithm (FA) and Particle Swarm Optimization (PSO) for band selection. The proposed method outperforms Genetic Algorithm (GA). Bedawi and Kamel (2011) used Particle Swarm Optimization (PSO) for classifying remote data over urban areas. The result shows the significance with high predictive accuracy. Zhang et al. (2011a) presented endmember extraction technique by employing Ant Colony Optimization (ACO) and compared the results to N-FINDR and VCA algorithms. Zhang et al. (2011b) proposed an endmember extraction method by means of Particle Swarm Optimization. Senthilnath et al. (2011a) used Discrete Particle Swarm Optimization in image registration and it turns out to be an efficient technique. Table 2 provides a detailed comparison.

Table 2 Comparative analysis from 2009 to 2011

Reference	Assigned Number	Classifier	Utility	Images Considered	Observation
(Mohammadzadeh et al. 2009	9	Fuzzy-PSO based method	Extraction of Roads	IKONOS satellite images	The effectiveness was reflected by the quality of the extracted road centerline.
(Maulik and Saha 2009)	10	Fuzzy Clustering Technique based on Modified Differential Evolution	Image Classification-l-and cover	IRS satellite and SPOT image of Calcutta and Mumbai IRS satellite image	MoDEFC constantly performed better than classical GAFC, DEFC, SAFC and FCM methods
(Chen and Leou 2009)	11	Particle Swarm Optimization	Imagery Fusion	High-resolution, low-resolution panchromatic and multispectral IKONOS satellite images	The visual quality and correlation coefficients were better and greater than the GIHS, BT, and SDF
(Juneja et al. 2009)	12	Fuzzy-Rough classifiers, Rough Set and Artificial Neural Network and	Image classification	LISS-III image	For image classification, the better choices are Rough Set and Rough-Fuzzy, as compared to ANN
(Paoli et al. 2009)	13	Particle Swarm Optimization	Unsupervised classification	AVIRIS data set	K-means and PCA (first 10 components) + fuzzy C-means were compared with the proposed technique and acquired promising performances in classification accuracy
(Daamouche and Melgani 2009)	14	Wavelet optimization within PSO structure.	Image classification	Hyperspectral AVIRIS data set	Method outperforms the Daubechies wavelets
(Chang et al. 2009)	15	Parallel Particle Swarm Optimization	Band Selection	PacRim-II Project Dataset	Proposed technique improved the computational load along with the achievement of more reliable quality of solution as compared to Greedy Modular Eigenspaces
(Ding and Chen 2009	16	Particle Swarm Optimization	Band Selection	AVIRIS 92AV3C dataset	In comparison to customary classifiers, obtained results confirmed the supremacy of the support vector machine technique and it was suggested that the further enhancements in classification precision can be achieved
(Papa et al. 2010)	17	Hybrid Particle Swarm Optimization-Projections Onto Convex Sets	Image Restoration	CBERS-2B satellite images	Compared with Wiener and Richardson–Lucy algorithms and better results were obtained
(Bedawi and Kamel 2010)	18	Particle Swarm Optimization	Clustering-based image segmentation	High resolution sensing images	Compact clustering results were generated as compared to the K-means algorithm.
(Linyi and Deren 2010)	19	Particle Swarm Optimization	Image Fuzzy Classification	Remote sensing images	Compared with genetic algorithm and mean value method. Higher accuracy was obtained and less training time was obtained.
(Ari and Aksoy 2010)	20	PSO based method for estimation of likelihood of Gaussian Mixture Models.	Unsupervised Classification	AVIRIS image	Better clustering results were obtained, as compared to the Expectation Maximization algorithm for estimating Gaussian Mixture Models.
(Gupta et al. 2011)	21	Extended Biogeography Based Optimization	Image Classification	Remote sensing images	Very accurate land-cover features were extracted.
(Halder et al. 2011)	22	Ant based algorithms	Classification and Clustering	SATIMAGE, IRS-1A, SPOT and IRS	Supervised APC performs better than Multilayer Perceptron and SVM. Unsupervised APC method performs better than MS and KM. Factors used were Rand, Jaccard and two external evaluation indices S_dbw and β

Table 2 (continued)

Reference	Assigned Number	Classifier	Utility	Images Considered	Observation
(Senthilnath et al. 2011b)	23	Glowworm Swarm Optimization	Image Classification	Thematic mapper image of Landsat 7	The performance of the model GSO was better than the MSC unsupervised method and is reasonable for classification.
(Goel et al. 2011)	24	Particle Swarm Optimization - Biogeography Based Optimization (PSO-BBO) hybrid approach	Image Classification	IRS-P6	The method is very efficient and accurate in terms of land cover feature extraction and the method can be extended to other global optimization problem.
(Arora et al. 2011)	25	Particle swarm optimization with morphological operators	Image Feature Classification	Google Earth images of Chandigarh and Saharanpur	The implemented approach has produced satisfactory results and can identify definite features such as vehicles, bridges etc.
(Samadzadegan and Mahmoudi 2011)	26	Particle Swarm Optimization and Firefly algorithm	Feature/Band Selection	AVIRIS data set	With respect to GA and PSO, FA is more superoior
(Bedawi and Kamel 2011)	27	Particle Swarm Optimization	Urban land-cover classification	University of Waterloo Map Library	PSO based rule discovery algorithm can be used in classification and was compared with Neural Network, Parzen window, linear discrimination and K-nn classifiers
(Zhang et al. 2011a)	28	Ant Colony Algorithms	Endmember Extraction	AVIRIS data set	Endemenber extraction problem can be handled correctly by ACO and achieve better results compared to N-FINDR and Vertex Component Analysis and Pure Pixel Index
(Zhang et al. 2011b)	29	Discrete Particle Swarm Optimization	Endmember Extraction	AVIRIS data set	DPSO was better than Vertex Component Analysis and N-FINDR
(Senthilnath et al. 2011a)	30	Discrete Particle Swarm Optimization	Image Registration Technique	QuickBird multispectral Image, QuickBird panchromatic image	Proposed approach is effective for multisensory satellite image registration.

Analysis from 2012 to 2014

Senthilnath et al. (2012) proposed hierarchical clustering procedure by using Glowworm Swarm Optimization (GSO), Niche Particle Swarm Optimization (NPSO) and Mean Shift Clustering (MSC), and it was observed that GSO based approach was robust and more accurate. Wang et al. (2012) presented PSO based approach for post-processing the Sub-Pixel Mapping (SPM) results obtained with the help of Sub-Pixel/Pixel Spatial Attraction Model (SPSAM). Yamaguchi et al. (2012) applied Particle Swarm Optimization (PSO) to the problem of similar image search by using the concept of transfer learning. Banerjee et al. (2012) attempted to solve the image classification land-cover problem by implementing Artificial Bee Colony (ABC) and the comparison was made with other methods. Soliman et al. (2012) worked in the field of image classification by using Support Vector Machine (SVM) and PSO, and evaluation revealed that the usage of RBF kernel function had utmost exactness ratio as well as polynomial kernel. Gao et al. (2012) implemented Ant Colony Optimization (ACO), for endmember extraction, based on GPU and the results were evaluated. Yavari et al. (2013) presented modified Particle Swarm Optimization (PSO) in identifying the ideal terms for Rational function models (RFM). Bhandari et al. (2014a) employed Cuckoo Search (CS) and Wind Driven Optimization (WDO) along with the use of Kapur's entropy for multilevel thresholding and revealed their efficiency and accuracy. Zarrinpanjeh et al. (2013) proposed ant-agent use in the updation of road map. Satisfactory results with respect to verification, detection and extraction of roads.

Senthilnath et al. (2013) used Genetic Algorithm (GA) and PSO for flood evaluation and river mapping and proved to be an accurate and reliable approach. Bhandari et al. (2014b) presented the application of Artificial Bee Colony algorithm with DWT-SVD for the enhancement in contrast. The proposed technique is better as compared to DCT-SVD, PSO, DWT-SVD, GHE and PSO's modified versions. Ghosh et al. (2013) designed a supervised feature selection method with the help of Self-adaptive Differential Evolution (SADE). The techniques also used the method of feature ranking. (Zhang et al. (2013) have proposed methods for improving ACO algorithm for extraction of endmember. Bhandari et al. (2014c) presented Cuckoo Search (CS) and DWT-SVD for contrast enhancement and comparison was done in terms of Standard Deviation, MSE, PSNR and Mean. Ghamisi et al. (2014) used fractional-order Darwinian Particle Swarm Optimization for multilevel thresholding. Significant improvement with respect to CPU time and fitness value was observed. Xue et al. (2014) proposed HA-PSO-SVM for image classification which improved the classification performance as compared to other technique. Zhong et al. (2014) proposed adaptive Differential Evolution for endmember extraction. The technique extracted endmember with higher precision. The detailed comparison is presented in Table 3.

Analysis from 2015 to 2018

Bhandari et al. (2015a) worked on finding the optimal multilevel thresholds by the use of modified Artificial Bee Colony (ABC) algorithm with various objective functions. The results are promising and minimized the computational time. Bhandari et al. (2015b) used Tsallis entropy function with Cuckoo Search (CS) algorithm for color image segmentation. The proposed technique selected very effectively and properly the threshold values. Agrawal and Bawane (2015) proposed new multiobjective Particle Swarm Optimization technique for determining different bands and the count of unseen layer nodes. Jayanth et al. (2015a) projected the use of Artificial Bee Colony (ABC) algorithm in satellite classification data and was compared with MLC, ANN and SVM. Ghamisi and Benediktsson (2015) proposed integrated Genetic Algorithm- Particle Swarm Organization (GA-PSO) for feature selection. It was confirmed that the approach automatically selected the most informative feature and was also tested for road detection. Senthilnath et al. (2015) used GA and NPSO for image registration and image clustering and the performance was compared to the conventional methods. Jayanth et al. (2015b) implemented Artificial Bee Colony algorithm for improving the performance of data classification. An enhancement of 5% was achieved in classification precision. Praveena and Singh (2014) presented the use of feed-forward neural networks classifier for image segmentation. Li et al. (2015) presented DPSO based flood inundation mapping- sub-pixel and comparison was done with other methods. Wang et al. (2015) proposed improved online dictionary learning involving Particle Swarm Optimization and the method had superior effect on noise suppression. Iounousse et al. (2015) developed an unsupervised technique on the bases of Probabilistic Neural Network and the accuracy results were compared with other methods. Upadhyay et al. (2010) used Artificial Neural Networks (ANN) for satellite image classification. Yang et al. (2015) developed a multi-agent system using Artificial Bee Colony (ABC) algorithm for the extraction of endmembers. The method solved the problem in high speed computing and distributive environments. Zhang et al. (2017) analyzed the role of swarm intelligence in the extraction of endmembers from hyperspectral images. Swarm intelligence provides a reliable solution. Kusetogullari et al. (2015) proposed Parallel Binary Particle Swarm Optimization for unsupervised change detection and compared the results with other methods. Suresh and Lal (2016) have implemented CS McCulloch for image segmentation. The results were compared with various techniques and were validated against by various measures. Singh et al. (2016) has presented a comparison of Artificial Bee Colony (ABC), Particle Swarm Optimization (PSO) and Cuckoo Search (CS) along with their hybrids for image enhancement. Sood and Menon (2016) proposed a hybrid Bat Algorithm-Cuckoo Search (BA-CS) approach for the discovery of best path for robotic navigation.

Bhandari et al. (2016) performed a comparative study of various wavelet filters for de-noising satellite images using CS, PSO and ABC. Senthilnath et al. (2016) proposed the implementation of Bat Algorithm (BA) in crop classification problem and compared the result with other intelligent algorithms. Gharbia et al. (2016) proposed image fusion method using Particle Swarm Organization (PSO). The method improved the spatial information and preserved spectral resolution. Tebbi and Haddad (2017) have proposed the use of Support Vector Machine (SVM) classifier in satellite image classification and the classification error was considerably reduced. Muangkote et al. (2016) presented an enhanced algorithm for the segmentation of image using Moth-Flame Optimization. The proposed method was more accurate and effective as compared to other traditional methods. Kusetogullari and Yavariabdi (2016) proposed the implementation of Self-Adaptive Hybrid Particle Swarm Optimization-Genetic Algorithm in obtaining change detection for Landsat multi temporal multispectral images. Sarkar et al. (2016) gave a novel unsupervised classification technique using DE and maximum Rényi entropy methods.

Tien Bui et al. (2017) implemented a novel hybrid Neural Fuzzy optimized by Particle Swarm Optimization (PSO-NF) technique for forest fire susceptibility modeling. Bhandari et al. (2017) proposed the implementation of Beta Differential Evolution (BDE) algorithm in image contrast enhancement. The results with respect to SSIM, EKI, MSE, PSNR and FSIM show the superiority over other traditional methods. Sachdeva et al. (2017) proposed a predictive model for flood susceptibility using PSO and SVM. K et al. (2016) reviewed the enactment of PSO and classifier such as Random forest to satellite images for enhancing and obtaining accurate model of Land Cover Classification. Chang et al. (2017) implemented a novel approach for dimensionality reduction. The Impurity Function band prioritization method uses PSO and

Table 3 Comparative analysis from 2012 to 2014

Reference	Assigned Number	Classifier	Utility	Images Considered	Observation
(Senthilnath et al. 2012)	31	Glowworm Swarm Optimization, Niche Particle Swarm Optimization and Mean Shift Clustering	Hierarchical Clustering-land cover mapping	QuickBird and Landsat 7 thematic mapper	GSO is computationally slow but gave better classification results. The NPSO method is slower and is also less efficient as compared to GSO
(Wang et al. 2012)	32	Particle Swarm Optimization	Post Processing of sub-pixel mapping	Indian Pine Test Site- HSI data and HJ-1 satellite image	The proposed approach provides high accuracy and also reduction in noise
(Yamaguchi et al. 2012)	33	PSO based on Transfer learning concept.	Similar Image Search	MODIS imagery	The proposed PSO method outperforms GA.
(Banerjee et al. 2012)	34	Artificial Bee Colony optimization	Land cover problem by image classification	LISS-III	Results are compared with the Minimum Distance Classifier, BBO, Maximum Likelihood Classifier, Membrane computing and Fuzzy classifier and effectiveness of the proposed method was observed.
(Soliman et al. 2012)	35	SVM and Particle Swarm Optimization	Image Classification.	ASTER satellite imagery	Results presented that the performance of projected approach using the RBF kernel function has got the highest normal overall precision and polynomial kernel function.
(Gao et al. 2012)	36	Ant Colony Optimization Endemember Extraction	Endmember Extraction	AVIRIS data set	It was revealed that the processing speed of ACOEE gets benefit by using GPU.
(Yavari et al. 2013)	37	Particle Swarm Optimization	Rational function models for extracting spatial information	IKONOS-Geo image and SPOT image	PSORFO has superiority with respect to degrees of freedom, computational time and sub-pixel accuracy
(Bhandari et al. 2014a)	38	Wind Driven Optimization and Cuckoo Search Algorithm	Image Segmentation	INSAT and five LANDAT	In multilevel thresholding problem, methods like WDO, ELR-CS and CS finds application because of their accuracy and efficiency
(Zarrinpanjeh et al. 2013)	39	Ant-Agent	Road Map Updation	GeoEye-1 pan-sharpen imagery	Observed results are satisfactory with respect to updated map production along with detection, verification and extraction of roads
(Senthilnath et al. 2013)	40	Genetic Algorithm and Particle Swarm Optimization	Segmentation and clustering	MODIS satellite images	The proposed algorithms offer accuracy and reliability in the extraction of water covered region
(Bhandari et al. 2014b)	41	Artificial Bee Colony algorithm using DWT-SVD	Augmentation in terms of contrast	INSAT and LANDSAT images	Better technique as compared to DCT-SVD, PSO, PSO's modified versions, General Histogram Equalization and DWT-SVD with respect to PSNR, mean, variance and MSE
(Ghosh et al. 2013)	42	Differential Evolution - Self-adaptive	Supervised Feature Selection	AVIRIS, Landsat, NASA Earth Observing 1 satellite	Results were compared with GA, ACO, ANTDE, DE and significant improvement was obtained in classification precision and Kappa coefficient
(Zhang et al. 2013)	43	ACO algorithm	Endmember Extraction	AVIRIS USGS library	Presented improvement over AOCEE algorithm issues
(Bhandari et al. 2014c)	44	Cuckoo Algorithm and DWT-SVD	Contrast Enhancement	INSAT images and LANDSAT images	Proposed method is superior with respect to Standard Deviation, MSE, Mean and PSNR
(Ghamisi et al. 2014)	45	Fractional-order Darwinian Particle Swarm Optimization	Image Segmentation	Multispectral Worldview Image and Hyperspectral ROSIS Image	Experimental results compared the proposed approach with the classical PSO and DPSO. A more robust method is presented along with higher prospective for locating the ideal thresholds set within less computational time
(Xue et al. 2014)	46	Support Vector Machine, Harmonic Analysis and	Hyperspectral Image Classification	AVIRIS and ROSIS data set	Proposed method improved performance, and a good balance was obtained between computational time and accuracy

Table 3 (continued)

Reference	Assigned Number	Classifier	Utility	Images Considered	Observation
(Zhong et al. 2014)	47	Particle Swarm Optimization and Adaptive Differential Evolution	Endmember Extraction	AVIRIS data set	ADEE adaptively presented better Endmember Extraction results with lower RMSE and a upper SAM and SAMSFF accuracy

Gravitational Search Algorithm for reducing the hyperspectral bands. Golovko et al. (2017) has proposed the use of convolutional neural network in low-quality satellite images for detection of solar photovoltaic panels. Google satellite images were used. Azarang and Ghassemian (2017) proposed a novel approach of image fusion for applications in remote sensing using particle swarm optimization for weight injections. WorldView-3 and QuickBird data set are considered for assessment. Kumar et al. (2016) showed implementation of PSO and K-means to cluster satellite images. The approach produced more condensed and augmented clusters than the K-means method alone. Gaba et al. (2017) developed a statistical model, which helps in learning and classifying object in hyperspectral images using combination of GSA and FODPSO. Alizadeh Naeini et al. (2018) considered satellite images of very high spatial resolution and proposed a novel object based feature selection method. Singh et al. (2017) has proposed the use of Moth Flame Optimization for image classification. The detailed comparison is presented in Table 4.

Discussion

It has been observed that different techniques have been applied in different sectors of satellite image processing. In segmentation of satellite images, Particle Swarm Optimization is most widely used followed by Cuckoo Search, Artificial Bee Colony, Differential Evolution, Wind Driven Optimization, Genetic Algorithm and Moth-Flame Optimization. Classification is covered by Particle Swarm Optimization, Unsupervised Artificial Immune Classifier, Ant Colony Optimization, Differential Evolution, Fuzzy-Rough Set, Biogeography Based Optimization, Glowworm Swarm Optimization, Artificial Bee Colony, Neural Network/ Convolutional NN, Bat Algorithm, Support Vector Machine and Moth-Flame Optimization. Feature/ Band Selection use Firefly Algorithm, Differential Evolution, Genetic Algorithm and Particle Swarm Optimization. Extraction of roads or map updation or cross-country path-finding is achieved by Cuckoo Search, Bat Algorithm, Ant Colony Algorithm and Particle Swarm Optimization. Particle Swarm Optimization discovers its use in Image Fusion or Similar Image, Image Restoration, Sub-Pixel Mapping, Rational Function Models and Online Dictionary Learning. For Endmember Extraction, Differential Evolution, Particle Swarm Optimization, Ant Colony Optimization and Artificial Bee Colony are implemented. Genetic Algorithm and Particle Swarm Optimization are implemented for Image Registration and Change Detection. Fire and Flood susceptibility model is implemented by Particle Swarm Optimization and Support Vector machine. Contrast/ Image Enhancement are done by using Differential Evolution, Particle Swarm Optimization, Cuckoo Search and Artificial Bee Colony. Clustering uses Particle Swarm Optimization and Glowworm Swarm Optimization, whereas De-noising is using Artificial Bee Colony, Particle Swarm Optimization and Cuckoo Search. The brief analysis of various artificial intelligent techniques with their application areas in satellite image optimization is depicted in Table 5. The statistical analysis is carried out by pie and column charts as shown in Fig. 1. From Fig. 1a, this is observed that in image segmentation, Particle swarm optimization has the maximum applications (31%) followed by Cuckoo Search (23%), Artificial bee colony algorithm (15%), wind driven optimization, genetic algorithm and moth-flame optimization, differential evolution (7%). From Fig. 1b, PSO has 43% applications with respect to image classification, followed by ant colony optimization, artificial bee colony algorithm and neural networks. Similarly, Fig. 1c, d, e, f, g and h represents the applications of various swarm-based techniques in different areas of image processing. [U13].

Conclusion

Remote sensing provides coverage of large areas to collect precise information in various applications such as agricultural fields, location of floods, forest fires, landscape and regional planning etc. The quality of satellite images is weather dependent and size of data base is huge. This makes the image processing task highly time consuming and cumbersome. Thus, there is a need for application of a suitable artificial intelligence technique to improve the image quality with smaller processing time. In this study, various artificial intelligence techniques such as PSO, ACO, ABC, bat algorithm, GA etc. have been analysed for optimization of satellite image

Table 4 Comparative analysis from 2015 to 2018

Reference	Assigned Number	Classifier	Utility	Images Considered	Observation
(Bhandari et al. 2015a)	48	Modified Artificial Bee Colony	Image Segmentation	Satellite images of Pléiades and NASA Earth Observatory	Comparison done with Genetic algorithm, ABC and PSO, and the objective functions considered were Otsu, Tsallis and Kapur's. The proposed method outperforms other methods with a limitation of high complexity.
(Bhandari et al. 2015b)	49	Cuckoo Search Algorithm	Color Image Segmentation	NASA Earth Observatory images	Compared Artificial Bee Colony, Differential Evolution, Particle Swarm Optimization, Wind Driven Optimization, and Cuckoo Search. Robustness order CS > DE > ABC > PSO > WDO. Good to bad run time, DE < ABC < CS < PSO < WDO and CS approach had very less control parameters
(Agrawal and Bawane 2015)	50	Multiobjective PSO	Image Classification	Landsat satellite images of Washington, DC	Improved the classification accuracy and computation reduction in the classification stage of neural classifier
(Jayanth et al. 2015a)	51	Artificial Bee Colony	Image Classification	Multispectral data of LISS-IV IRS P6 and panchromatic image of IRS P5	The comparison is made between ABC, Maximum Likelihood Classifier, ANN and SVM methods and ABC was found out to be most effective in classification and the limitation observed is with respect to larger number of classes in feature space. No initialization of parameters is required and fast feature selection method
(Ghamisi and Benediktss-on 2015)	52	Hybrid Genetic Algorithm and Particle Swarm Optimization	Feature Selection Technique	AVIRIS Indian Pines and RGB Toronto Roads data set	The proposed technique was able to locate informative bands w.r.t. classification accuracies in a tolerable CPU time. The technique can also be used in road detection and as fitness function SVM is considered. The technique can handle high-dimensional data through the use of limited quantity of training examples in comparison to various selection methods.
(Senthilnath et al. 2015)	53	Genetic Algorithm and Niche Particle Swarm Optimization	Image Registration and Image Clustering	LISS-III and SAR	Performance of SIFT-GA was better than SIFT-ANN for Image registration and also the performance of NPSO is superior as compared to ISODATA
(Jayanth et al. 2015b)	54	ABC algorithm	Image classification	L1SS-IV sensor of IRS P-6 and PAN image of IRS P-5 satellites	The comparison was made between the MLC and ABC method by making use of OCA and kappa statistics. ABC technique is more compelling for the classification. No initialization of parameters is required and fast feature selection method
(Praveena and Singh 2014)	55	Hybrid ABC-FCM algorithm	Land-cover mapping-image segmentation	Satellite images	The performance was compared with Moving KFCM, ABC algorithm, and ABC-GA algorithm and it outperformed the other methods.
(Li et al. 2015	56	Discrete Particle Swarm Optimization	Flood inundation mapping through Sub-pixel	Landsat ETM + images	Compared the proposed approach with traditional BPGDX-SFIM, BPBR-SFIM, DESDSFIM and SAM-SFIM methods. The approach dependably accomplished more precise sub-pixel mapping conclusions as far as visual and quantitative assessments
(Wang et al. 2015)	57	Particle Swarm Optimization	Online dictionary learning	Landsat-8 images and HJ-1-A	The proposed method improved the performance of ODL algorithms with respect to accuracy and has an improved effect on noise suppression

Table 4 (continued)

Reference	Assigned Number	Classifier	Utility	Images Considered	Observation
(Iounousse et al. 2015)	58	Neural Network-Probabilistic	Land use classification	LANDSAT and SPOT data set	Better performance and accurate classification with around 3.44% of error as compared to K-means and fuzzy c-means
(Upadhyay et al. 2010)	59	Artificial Neural Network	Image classification	IRS P-6 LISS-III	The results expressed that if the number of neurons are increased in ANN then the accuracy downfall is observed in classification based on neural networks.
(Yang et al. 2015)	60	Artificial Bee Colony	Endmember Extraction	AVIRIS data set	ABC algorithm implemented in MAS is capable of reducing the computing time by the introduction of additional distributed computing nodes which share the calculating cost efficiently
(Zhang et al. 2017)	61	Artificial Bee Colony	Endmembers Extraction from hyperspectral imagery.	AVIRIS data set	For endmember extraction, ACO, DPSO, and ABC have been introduced. Outstanding global optimization search ability was reflected by the good results.
(Kusetogullari et al. 2015)	62	Parallel Binary Particle Swarm Optimization	Unsupervised change-detection	USGS-Landsat satellite and Earth Resources Observation and Science Centre	Performance comparison was done with EM-, GA- MRF- and PCA- based methods. For showing the superiority, real world and semi-synthetic data sets were used for quantitative and qualitative tests
(Suresh and Lal 2016)	63	Cuckoo Search	Image segmentation	Pleiades Satellite Imagery	The performance with respect to Otsu's method, Kapur and Tsallis entropy was compared with ABC, Darwinian Particle Swarm Optimization, PSO, CS and CS Mantegna algorithm with and validation was achieved by the means of PSNR, MSE, FSIM and CPU running time
(Singh et al. 2016)	64	CS, PSO, ABC and hybrids	Image Enhancement	Satellite Images	Analytical review comparing all the techniques with respect to mean, MSE, PSNR and variance
(Sood and Menon 2016)	65	Bat-Cuckoo Search	Cross-country Path finding	Satellite images	The proposed hybrid approach can rapidly plan an optimized path in complex surroundings.
(Bhandari et al. 2016)	66	Cuckoo Search, Artificial Bee Colony and Particle Swarm Optimization	De-noising of satellite images	INSAT and LANDSAT	For noise suppression and edge preservation, Meyer wavelet filter-based CS de-noising technique was compared to other wavelet-filter methods and better performance was obtained
(Senthilnath et al. 2016)	67	Bat Algorithm	Image Classification	University of California, Irvine (UCI) repository	The performance of the algorithm was equated with existing hybrid BA with K-means, Particle Swarm Optimization and Genetic Algorithm and it was concluded that the BA can be functional to crop classification
(Gharbia et al. 2016)	68	Particle Swarm Optimization	Image Fusion	ASTER, SPOT, MODIS, ETM+ and MSS satellite	Comparison was done with the PCA and DCT. Improvement in fusion quality, spatial information and preserved spectral resolution. PSO based adaptive fusion rule can be implemented for improving performance of any image fusion technique
(Tebbi and Haddad 2017)	69	SVM	Cloud Classification	Meteosat Second Generation (MSG0 satellite images.	Elimination of non-rainy clouds by the proposed method improves the precipitation estimation
(Muangkote et al. 2016)	70	Moth-Flame Optimization Algorithm	Image Segmentation	Satellite Images	The method was more accurate and effective as compared to PSO, ABC, DE, MFO and GA.
	71				

Table 4 (continued)

Reference	Assigned Number	Classifier	Utility	Images Considered	Observation
(Kusetogullari and Yavariabdi 2016)		Hybrid Particle Swarm Optimization-Genetic Algorithm (Self-Adaptive)	Unsupervised Satellite Change Detection Method	Multi Spectral Multi Temporal Landsat Images	It augments the change detection and is able to discover the ultimate change detection mask.
(Sarkar et al. 2016)	72	Differential Evolution	Image segmentation	ROSIS and AVRIS sensors	DE based segmentation method by employing Rényi entropy is proposed. Performance is compared with ABC, CS, GA and PSO.
(Tien Bui et al. 2017)	73	Neural Fuzzy optimized by Particle Swarm algorithm	Forest fire susceptibility modeling.	Landsat-8 Operational Land Imagery	Proposed model outperforms the RF and the SVM model. Early warning system could also be established for tropical forest fires.
(Bhandari et al. 2017)	74	Beta Differential Evolution (BDE) Algorithm	Image Enhancement	Colored Satellite Images	The satisfactory results with respect to SSIM, EKI, MSE, PSNR and FSIM were compared with ABC, PSO, DE algorithms and modified ABC
(Sachdeva et al. 2017)	75	PSO and SVM	Flood Susceptibility	Remote Sensing and Geographic Information Systems	The model was compared with NN and RF, and it outperformed with an accuracy of 96.55%. District of Chamoli, Uttarakhand was considered.
(K et al., 2016)	76	PSO and classifier such as Random forest	Enhancing and obtaining accurate model of Land Cover Classification.	Satellite Images	Literature survey covering the performance of PSO and RF
(Chang et al. 2017)	77	Gravitational Search Algorithms and Particle Swarm Optimization	Dimensionality Reduction	Hyperspectral data sets	Hyperspectral data dimensionality is reduced by the proposed technique and obtained an improved classification accuracy as compared to other methods
(Golovko et al. 2017)	78	Convolutional Neural Network	Classification-detection of solar photovoltaic panels	Google Satellite low quality images	Obtained detection with high accuracy and low rate incorrect classifications
(Azarang and Ghassemian 2017)	79	Particle Swarm Optimization	Image Fusion	WorldView-3 and QuickBird	PSO is an effective method for image fusion
(Kumar et al. 2016)	80	K Means Algorithm and PSO	Satellite Image C1ustering	Landsat 8 OLI	The approach produced more condensed and augmented clusters than the K-means method alone.
(Gaba et al. 2017)	81	SVM, Finite Order Darwinian PSO and Gravitational Search Algorithm,	Image Classification	Hyperspectral data set of Indian Pine	Better accuracy is obtained as compared to FODPSO
(Alizadeh Naeini et al. 2018)	82	Particle Swarm Optimization	Feature selection (Object Based-OBF)	WorldView-2 sensor	PSO approach had better performance over GA, ABC and honey-bee mating
(Singh et al. 2017)	83	Moth-Flame Optimization	Image Classification	LISS-III sensor	Proposed method was better than fuzzy classification, Membrane Computing, BBO, minimum Distance Classifier and MLC

data. The detailed analysis revealed that Ant Colony Optimization finds its applications in the field of classification and extraction of endmember from hyperspectral data. Bat Algorithm, Artificial bee colony and Neural Networks work for classification and Cuckoo search algorithm deals with segmentation. This has been observed that Particle Swarm Optimization is the most commonly utilized strategy with respect to image classification, segmentation, feature/band selection, enhancement, image fusion, registration and restoration. The major areas covered by various techniques are land use-land cover mapping, crop classification, forest fire susceptibility and flood assessment. In future, these techniques need to be applied to other significant areas such as natural calamities forecast, suggestions for quick and efficient relief

Table 5 Image optimization techniques for satellite images

Application area for image optimization	Techniques and hybrid techniques	Assigned number from Tables 1,2,3 & 4
Segmentation	Particle swarm optimization	1, 18, 40, 45
	Differential evolution	73
	Artificial bee colony	48, 55,
	Cuckoo search	38, 49, 63
	Wind driven optimization	38
	Genetic algorithm	40
	Moth-flame optimization	70
Classification	Particle swarm optimization	3, 5, 7, 8, 14, 19, 20, 24, 25, 27, 35, 46, 50, 77, 82
	Unsupervised artificial immune classifier	2
	Ant colony optimization	3, 5, 6, 22
	Differential evolution	10
	Fuzzy-rough set	12
	Biogeography based optimization	21, 24
	Glowworm swarm optimization	23
	Artificial bee colony	34, 51, 54
	Neural Network/ Convolutional NN	58, 59, 79
	Bat Algorithm	67, 72
	Support Vector Machine	69
	Moth-flame optimization	84
Feature / Band Selection	Firefly algorithm	26
	Differential evolution	42
	Particle swarm optimization	4, 26, 52, 83
	Genetic algorithm	52
Extraction of Roads/ Road Map Updation/ Cross Country Path Finding	Particle swarm optimization	9
	Ant Colony Optimization	39
	Cuckoo search	65
	Bat algorithm	65
Image Fusion/ Similar Image	Particle swarm optimization	11, 33, 68, 80
Image Restoration	Particle swarm optimization	17
Endmember Extraction	Ant colony optimization	28, 43, 36
	Differential evolution	47
	Particle swarm optimization	29
	Artificial Bee Colony	60, 61
Image Registration	Particle swarm optimization	30, 53
	Genetic algorithm	53
Contrast / Image Enhancement	Particle swarm optimization	64
	Differential evolution	75
	Cuckoo search	44, 64
	Artificial bee colony	41, 64
Clustering	Particle swarm optimization	31, 89
	Glowworm swarm optimization	31
Sub-Pixel Mapping	Particle swarm optimization	32, 56
Rational Function Models	Particle swarm optimization	37
Online Dictionary Learning	Particle swarm optimization	57
Change Detection	Particle swarm optimization	62, 71
	Genetic algorithm	71
De-Noising	Artificial bee colony algorithm	66
	Cuckoo search	66
	Particle swarm optimization	66
Fire/ Flood Susceptibility	Particle swarm optimization	74, 76
	Support vector machine	76

operations and estimation of natural resources. The use of hybrid techniques by combining one or more artificial intelligence for remote sensed image optimization can also be performed. [U15].

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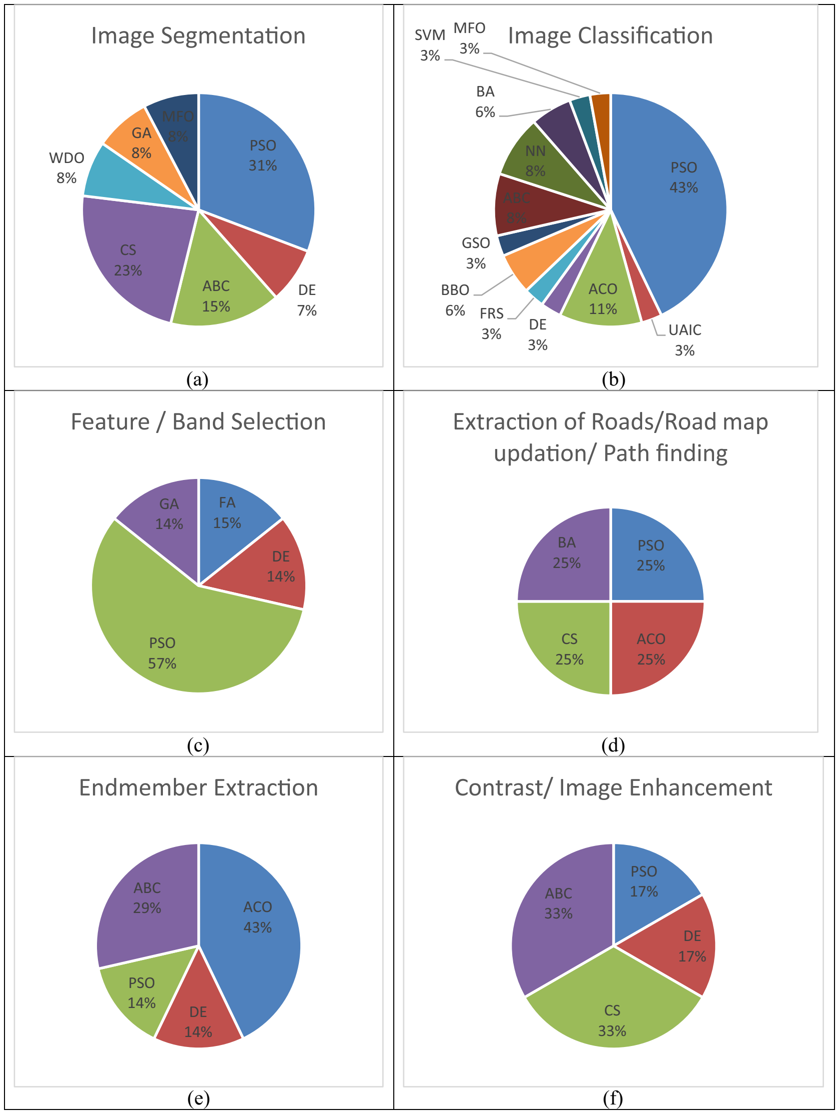

Fig. 1 Application areas of Swarm Intelligence Techniques in various fields of Image processing: (**a**) Segmentation, (**b**) Classification, (**c**) feature/band selection, (**d**) extraction of roads, (**e**) endmember extraction, (**f**) contrast/image enhancement, (**g**) De-noising, fire/flood susceptibility, clustering, registration and change detection, (**h**) other areas [U14]

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