Aswan University Journal of Science and Technology Vol. 2, issue 2, December 2022

Image Segmentation Using Hybrid Optimization Algorithms: A Review

Heba G. A. Yahia[1], Ashraf Mohamed Hemeida[2,*], Hameda A. Sennary[2]
[1] Computer Section, Mathematics Department, Faculty of Sciences, Aswan University, 81528 Aswan, Egypt
[2] Electrical Engineering Department, Faculty of Energy Engineering, Aswan University, 81528 Aswan, Egypt

Abstract: Image segmentation, often based on the properties of image pixels, is a widely used method in digital image processing and analysis to divide an image into multiple parts or areas. The main goal of image segmentation is to simplify the image for easier analysis. It would be very difficult to implement computer vision without performing image segmentation. An important component of computer vision is image segmentation, which has numerous commercial applications. Google and others Image-based search engines use image segmentation algorithms to identify the objects in your image and match their results to the relevant images they find to present you with search results.

Keywords: Image segmentation; Optimization algorithms; Hybrid optimization algorithms.

1. Introduction

Often based on the properties of the picture's pixels, image segmentation is a widely used method in digital image processing and analysis to divide an image into various parts or areas. It entails breaking down a picture into several pixel sections that are each represented by a mask or labelled image. Image segmentation's main objective is to make the image simpler for easy analysis. For image analysis, it is the initial stage. You would have a very difficult time implementing computer vision without doing image segmentation. A significant component of computer vision is image segmentation, which has numerous commercial applications. Advanced security systems and facial recognition software in your phone both employ image segmentation to identify your face. Utilizing technologies for number plate identification, a traffic system can identify a car and learn information about its owner. Google and other image-based search engines utilize image segmentation algorithms to identify the objects in your picture and match their findings with the pertinent images they find to present you with search results. In the medical field, picture segmentation is used to locate and classify cancer cells, measure tissue volumes, simulate surgeries virtually, and navigate while performing surgery.

1.1 Medicine and Dentistry:

By utilizing a multilayer thresholding image segmentation (MTIS) approach based on an augmented multiverse optimizer, COVID-19 chest films can be processed more effectively (CCMVO). An enhanced multiverse optimizer (MVO)-based algorithm called multilevel thresholding image segmentation (MTIS) is used to increase the processing effectiveness of COVID-19 chest film. Levy CLACO is a novel ant colony optimizer for continuous domains that combines the Cauchy mutation and the greedy Levy mutation. The better performance of CLACO in terms of search capability, convergence speed and ability to jump out of the local optimum is demonstrated by comparison with several relevant versions and other top competitors. Multilayer COVID-19 X-ray picture segmentation based on swarm intelligence optimization is being researched by researchers at Aberystwyth University [1]. The process of MVO is shown in Fig. 1. [1]. A novel approach to improve the Salp Swarm Algorithm (SSA), namely EHSSA is presented, and applied to MIS. It is a Comprehensive study of breast cancer microscopy [2]. The flowchart in Fig. 2. Shows the steps of this optimized approach [2].

Corresponding author E-mail: ashraf@aswu.edu.eg

Received December,26, 2022, received in revised form, January 5, 2023, accepted January 5, 2023.

(ASWJST 2022/ printed ISSN: 2735-3087 and on-line ISSN: 2735-3095) https://journals.aswu.edu.eg/stjournal

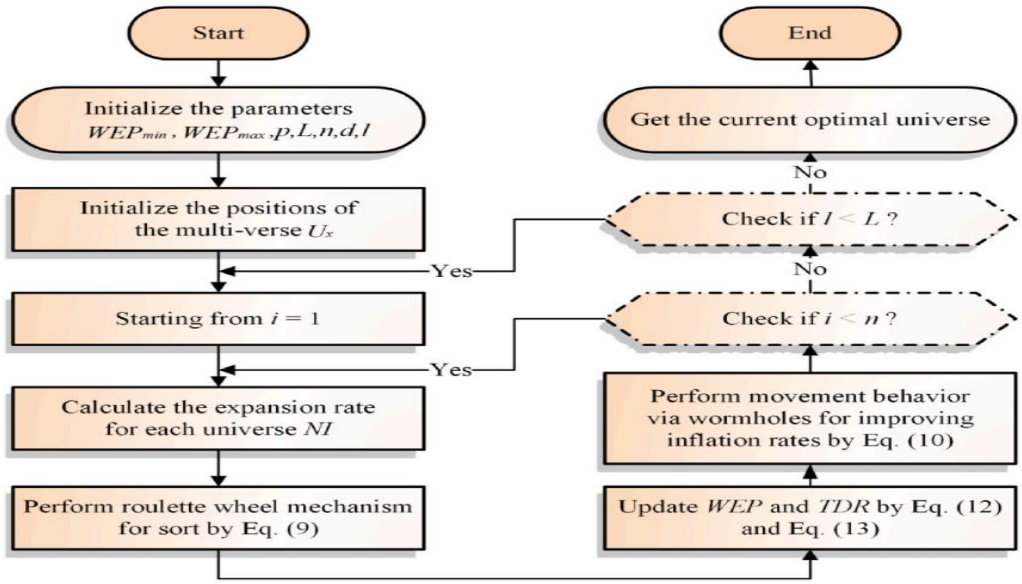

Fig. 1. Process of CCMVO [1]

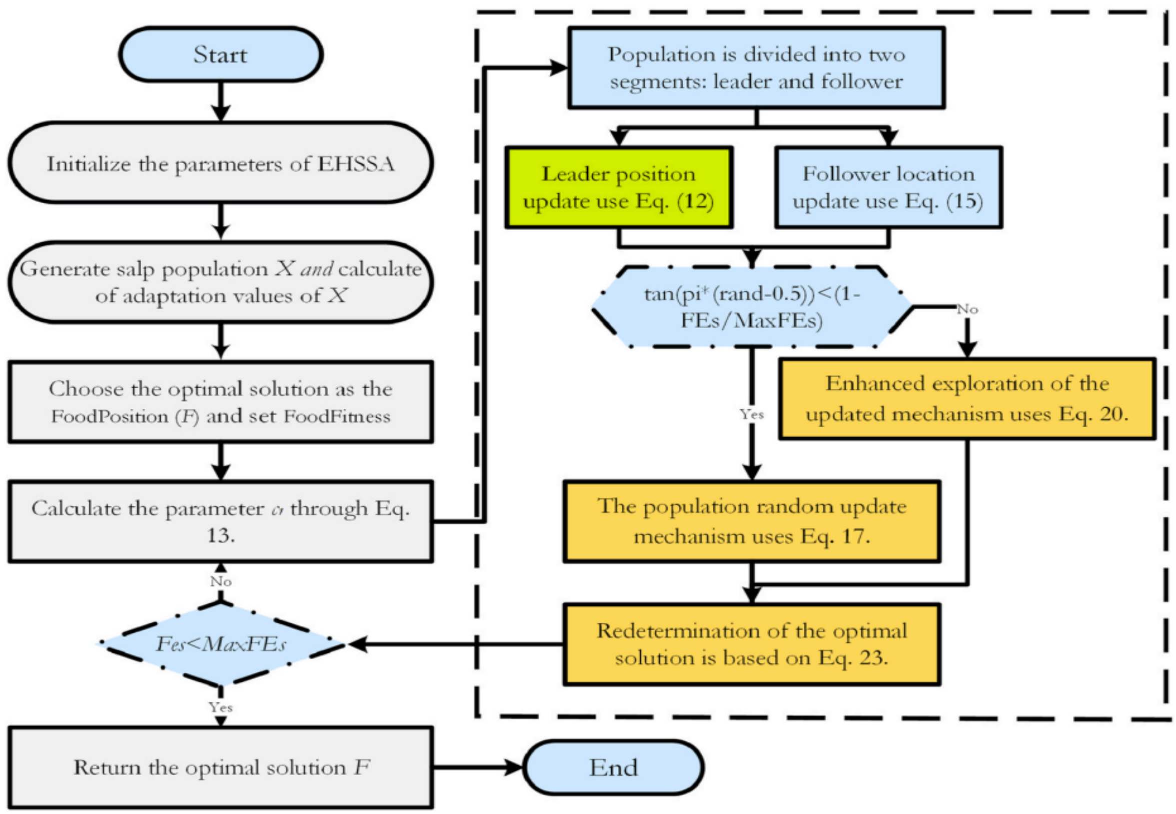

Fig. 2. Steps of SSA [2]

Renyi's entropy multi-threshold image segmentation based on an improved Slime Mould Algorithm (SMA) is discussed by introducing the diffusion mechanism (DM) into the original SMA. Then adding the association strategy (AS) to help the algorithm find the optimal solution faster. And then applying the algorithm to non-local means 2D histogram. The slime mould algorithm (SMA) serves as inspiration for the modified differential evolution (MDE) method, which is proposed with a vision based on slime mould foraging behavior [3]. To growth the diagnostic degree of COVID-19, a completely unique CLACO-primarily based totally multilevel X-ray photo segmentation method changed into tested the usage of swarm intelligence optimization. CLACO-MIS changed into correctly used to segmentation of COVID-19 X-ray images the usage of 2D Kapur's entropy because the CLACO health characteristic primarily based totally on 2D histograms which includes non-neighborhood imply filtered pics and grayscale pics. A contrast of CLACO with positive similar variations and different remarkable friends suggests that CLACO outperforms them in phrases of seek capability, convergence speed, and cap potential to leap past the neighborhood optimum [4]. A changed differential evolution (MDE) set of rules with an imaginative and prescient primarily based totally on slime mold foraging conduct changed into presented, taking suggestion from the formerly introduced slime mold set of rules (SMA). The evolved version is an incredible segmentation technique which can offer realistic assist for destiny studies into breast invasive ductal carcinoma. and created an extraordinary MDE-primarily based totally multilevel photo segmentation version to obtain incredible breast cancers photo segmentation results [5]. Based on a non-local mean 2D histogram and 2D Kapur's entropy, the SSA with Gaussian Barebone and Stochastic Fractal Search (GBSFSSSA) is a statistical analysis. Data analysis revealed that it outperformed the comparison algorithm overall. The algorithm is also used to segment COVID-19 CT images, and a study of the data revealed that it considerably improved the segmentation of medical images and outperformed the comparison algorithm in terms of overall performance. Using COVID-19 chest X-ray pictures, a computational method is developed that can quickly and accurately determine the severity of an illness. To improve the level of diagnosis, a modified whale optimization approach with population reduction (mWOAPR) was applied. [6,7]. By merging an enhanced slime mould method (ASMA), where ASMA is primarily implemented by introducing the position update mechanism of the artificial bee colony (ABC) into the SMA, a multilayer thresholding image segmentation (MLTIS) approach is given. The outcomes of the experiment completely show that ASMA can produce high-quality solutions and nearly never experiences premature convergence. The ASMA approach has a lot of potential to be employed as an image segmentation method for lupus nephritis (LN) images because it can be an effective swarm intelligence optimization method that can maintain a delicate balance during the segmentation process [8]. Combined horizontal and vertical search mechanisms (CCABC) could be used to increase the effectiveness of the artificial bee colony algorithm (ABC). It verifies that the new MTIS approach has a good segmentation performance, and that the analysis of relevant evaluation criteria shows that the incorporation of CCABC in MTIS is very successful [9]. For the segmentation of medical images, the optimization-based implicit model agnostic meta-learning (iMAML) approach was presented in few-shot conditions. The suggested method significantly outperforms the naive supervised baseline model and two other approaches, according to results on skin and polyp datasets [10]. A dual-scale multi-modality perceptual adversarial network (DualMMP-GAN) is proposed for brain tumors. A GMMS, which combines provided modalities with generated modalities, is also proposed. According to experimental findings, the GMMS performs better than the CycleGAN. Additionally, segmentation by GMMS yields higher results than segmentation by a single modality in terms of dice, sensitivity, specificity, and Hausdorff95 [11]. Feature Guided Attention Module (FGAM) is a simple yet flexible and useful module for medical picture segmentation. Features are mined for their capacity to represent features by the FGAM. The module has a parameter-free activator and can be removed following training of different encoder-decoder networks [12]. Using a new lesion morphology aware network, breast cancers in 2D magnetic resonance images may be segmented (MRI). Using a new lesion morphology aware network, breast cancers in 2D magnetic resonance images may be segmented. Two stages—the stage for breast segmentation and the stage for tumor segmentation make up the proposed network's hierarchical structure. This technique produces excellent segmentation results and outperforms state-of-the-art techniques, indicating that it has a good chance of being used in clinical settings [13]. For learning with less labelled data, a task-driven data augmentation approach is presented forth. The generator of the suggested technique uses two sets of transformations. Additive intensity transformations and deformation fields simulate fluctuations in intensity and shape. In a semi-supervised framework, both transformations are optimized using labelled and unlabeled instances. Our tests on the heart, prostate, and pancreas medical datasets demonstrate that the suggested technique greatly outperforms traditional augmentation and semi-supervised algorithms for picture segmentation in the context of inadequate annotation [14]. A developed technique that optimizes the CNN and CRF parameters while using CNN-learned features in a CRF. It is better than the current approaches when compared to CRF's techniques in terms of Dice coefficient, average volume difference, and lesion-wise F1 score. We used the segmentation of the aorta and pulmonary arteries in non-contrast CT, as well as multi-modal MRI [15]. A Fuzzy C-Means (FCM) clustering algorithm is a classic method for segmenting Magnetic Resonance (MR) pictures. The initial cluster centers in the FCM method are selected at random, whereas the cluster centers are selected ideally with the aid of the PSO algorithm [16]. The suggested architecture uses a logistic function to establish likelihood appearance and prior label probabilities depending on a generic shape function. A Gauss-Newton optimization step estimates the posterior probability of the shape parameters. The findings demonstrate performances that are on par with supervised approaches and superior to previously suggested unsupervised ones [17].

1.2 ENGINEERING APPLICATIONS OF ARTIFICIAL INTELLIGENCE:

For quick image segmentation, the hybrid active contour model powered by optimal local pre-fitting image (OLPFI) energy was suggested. This model can correctly segment images with intensity inhomogeneity or weak boundaries. The energy sign function can adaptively choose the motion direction based on picture data. According to experimental findings, the model is quite effective at segmenting pictures [18]. Results on photos of various objects have demonstrated that the model is more robust than existing models. It may traverse spurious borders and execute a valid segmentation for low contrast pictures using an adaptive interpolator function. It may traverse spurious borders and execute a valid segmentation for low contrast pictures using an adaptive boundary indicator function with a threshold determined by the standard deviation of the images to be identified [19]. The use of meta-learning for picture segmentation is reviewed. Meta-learning models are divided into model-based, optimization-based, and metric-based categories. A thorough comparison is made between the current techniques and those of alternative approaches. Afterward, classifying the currently used meta-learning techniques into model-based, optimization-based, and metric-based categories [20]. A novel technique is put forward for the reliable, automated separation of plants from background in color (RGB) photographs. It automatically involves thresholding the contrast-enhanced photos after unrestricted optimization of a linear combination of RGB component images to improve the contrast between plant and background regions. The accuracy of plant segmentation and picture contrast was assessed for the CEIs and ten common index photos. Based on the greatest foreground-background separability, the CEI photos consistently outperformed the index photos in terms of visual contrast [21]. In the field of computer vision, watershed segmentation is frequently employed. The picture is pre-processed using a new filter (OLS operator). Based on picture decompositions, the new filter may smooth the image while maintaining sharper edges across various regions. This technique can more precisely segment pictures than the conventional watershed method [22]. DPSOK is a new picture segmentation method based on dynamic particle swarm optimization (DPSO) and K-means clustering. When segmenting images, the DPSOK technique clearly outperforms the traditional particle swarm optimization of PSOK. According to experimental findings, the PSOK algorithm can significantly enhance its capacity to do global searches [23]. The ultimate object recognition might be achieved, however, using the CNN refining approach. One CNN has suggested optimizing segmentation using refinement-based object recognition to boost the accuracy of object recognition. On the one hand, feature extraction may benefit from an efficient segmentation algorithm [24]. To tackle global optimization and multilayer image segmentation issues, a modified version of the Manta ray foraging optimizer (MRFO) technique is described. MRFO models manta rays' foraging behavior which seeks to improve its capacity for exploitation. Fractional-order (FO) calculus has a strong ability to support the Meta heuristic optimization methods by adequate memory, it is used to achieve this change. [25]. The suggested RGB-D segmentation approach performs better than the other methods. For RGB-Depth pictures, a brand-new technique called random Henry gas solubility optimization-fuzzy clustering approach has been developed [26]. The Quantum Genetic Algorithm (QGA) employs the qubit encoding of people. For comparative purposes, the Particle Swarm Optimization method (PSO) was also applied. It has been demonstrated that in the optimization job, the QGA exceeds the GA and the PSO greatly outperforms both methods [27]. Intelligent Fuzzy Level Set Method (IFLSM) and Improved Quantum Particle Swarm Optimization (IQPSO) are presented for picture segmentation. Using Magnetic Resonance Imaging (MRI) pictures to segment brain tissues yields the best results when the suggested work is put into practice [28]. Chaotic Darwinian Particle Swarm Optimization (CDPSO) has been developed. This approach mitigates the issue of early convergence by substituting chaotic sequences for random sequences. For a satellite image segmentation scenario, various histogram thresholding measures, including minimal cross entropy and Tsallis entropy, were utilized as goal functions [29]. Multi-population BBO (MPBBO), an upgraded WRBBO, is suggested. A multi-population technique is first implemented. The experimental results outperform other cutting-edge algorithms in terms of search ability and efficiency. FRFCM-MPBBO has more stability than traditional techniques, according to the findings of using MPBBO to image segmentation with rapid and resilient fuzzy c-means (FRFCM) [30]. For image segmentation, an active contour model is developed that combines scalable region-fit energy with optimized Laplacian-Gaussian (LoG) energy. The suggested model is insensitive to starting contour locations and produces an appropriate segmentation result after the inclusion of the LoG term [31]. Intensity distribution in crowded pictures often follows a near constant fluctuation in various places. To segment crowded pictures, a statistical region-based Active Contour Model (ACM) is proposed. This model considers the link between local and global image statistics. The suggested ACM's regional energy term is then created in a way that minimizes the disparity between local states. The presence of a global optimum solution and less sensitivity to contour initialization are the key advantages of graph-based formulation over level set formulation [32]. Many edge-based approaches for intima-media thickness (IMT) estimation employ DE speckling and augmentation techniques to get over the drawbacks of manual segmentation. A wind driven optimization (WDO) approach is used to show a completely automated region-of-interest (ROI) extraction and a threshold-based segmentation of the intima media complex (IMC) [33]. The lesions on the COVID-19 CT scan exhibit different patterns of ground-glass opacity and consolidation that can be seen in either the left or right lung, or in both lungs. The lobes of the lungs are irregular and have a grey color that is comparable to the arteries, veins, and bronchi nearby. A lung parenchyma segmentation approach based on two-dimensional reciprocal cross entropy multi-threshold is suggested. With a high segmentation accuracy rate, the contrast clarity of CT images has increased the accuracy of lung pulmonary fibrosis segmentation [34]. Multilevel thresholding is used to segment Magnetic Resonance Image (MRI) brain pictures using adaptive wind driven optimization (AWDO). For image segmentation, the axial T2-weighted MRI brain images are considered. The outcomes demonstrated the superiority of the suggested strategy in terms of improved segmentation outcomes [35]. The MGSMA-based MLIS methodology is compared to eight other comparable approaches at both high and low thresholding levels, with some pertinent experimental data to support its claims, to show that it can produce high-quality segmentation results. There is little doubt, then, that MGSMA is a high-performance swarm intelligence optimization strategy, and that the MLIS method based on MGSMA can yield high-quality segmentation results [36]. The Gaussian mutation, Levy flight, and opposition-based learning are used to improve the EPO algorithm. The Kapur's multi-threshold approach is optimized by the IEPO algorithm for use in tests on Berkeley pictures, satellite photos, and plant canopy images. According to the experimental findings, EPO is the most efficient technique for segmenting-colored images [37]. Scientists have developed a unique strategy to improve the fundamental FPA flower pollination algorithm. To improve the fundamental FPA local search capability and adaptively adjust the harmonization coefficient among the FPA exploration and exploitation cores, fractional-order (FO) calculus characteristics are applied [38]. The use of a random spare technique mostly increases convergence speed. Additionally, it has been found that improved RCACO's capacity to step out of LO is more dependable than previous approaches. The chaotic intensification approach and enhanced selection mechanism are used to the continuous version of the ant colony optimizer (ACOR) to significantly increase the capacity to step out of LO and to refine the convergence accuracy [39]. Marine Predators Algorithm (MPA), a contemporary meta-heuristic algorithm, is improved by utilizing Opposition-Based Learning (OBL), known as MPA-OBL, to increase search efficiency and convergence. Post-hoc analysis shows that, when compared to the other competitor algorithms, the MPA OBL achieves extremely effective and trustworthy outcomes [40]. The widely used metaphoric algorithm known as the "grey wolf optimizer" (GWO) is built on improved versions of the "velocity-free particle swarm optimizer." The multi-stage grey wolf optimizer (MGWO) is a suggested improvement to the GWO. As a result, the suggested MGWO can have a better outcome. The outcomes demonstrated the MGWO's competitiveness and its viability as a multi-threshold picture segmentation optimizer [41]. The between-class variance (Otsu method) is offered as the objective function for an enhanced multi-threshold image segmentation technique based on the whale optimization algorithm (RAV-WOA). When performing image segmentation on grayscale and color images, it can choose acceptable optimal thresholds while ensuring high efficiency and quality. The reverse learning strategy pits the current whale population against its reverse population to improve the initial population's quality. [42]. A technique for segmenting images based on super pixels is suggested. Synthetic aperture radar (SAR) picture segmentation is accomplished using it. The suggested approach can segment SAR data with outstanding precision, according to experimental results. A suggested strategy is possible to improve segmentation performance for application extensions [43]. Recent research has focused on using spatial information or previous knowledge to ensure anatomically realistic segmentation. As seen by the expanding body of work on the subject, it is now an expanding trend in CNN-based picture segmentation. Employing the high level prior incorporated at the loss function level as the main emphasis. Current methodologies' advantages and disadvantages are discussed, along with the difficulties associated with designing and integrating prior-based losses and optimization techniques, and future research areas are suggested [44]. FCEDN is an optimized version of the Exponential Neighborhood Grey Wolf Optimization (EN-GWO) model. The object form, size, topology, and inter-regional restrictions are used to categorize articles based on the prior's kind. Results show that the FCEDN model achieves better outcomes than the other optimization techniques and other most recent deep learning approaches. [45]. The enhanced bee colony algorithm for multi-objective optimization is a novel technique for segmenting-colored images. PSO IBMO algorithm is based on a multi-Objective optimization algorithm (IBMO). The comparison of manually labelled and experimentally acquired segmentation results demonstrated the viability of the suggested concepts [46]. Using two-dimensional (2D) Kullback-Leibler (K-L) divergence and modified Particle Swarm Optimization, a segmentation technique is suggested to enhance the efficacy and efficiency of multilevel picture thresholding segmentation (MPSO). The MPSO overcomes the disadvantage of premature convergence of PSO by improving the location update formulation and the global best position of particles, and drastically reduces the time complexity of multilevel thresholding segmentation [47] A method is suggested to locate the tumor area that is bordered by edematous and normal tissue areas. Bacteria Foraging Optimization (BFO) and Modified Fuzzy K Means algorithm (MFKM) are utilized. It has generated notable sensitivity and specificity values. To perform an effective analysis of MR brain images, the optimization and clustering techniques Bacteria Foraging Optimization (BFO) and Modified Fuzzy K Means algorithm (MFKM) are utilized [48]. To get bacteria to forage along nutrient-rich areas in a manner that resembles Escherichia coli, we represent the gradients of intensities as the nutrient concentration. A bacterial foraging-based edge detection (BFED) method is suggested. BFED algorithm delivers more precise cell picture segmentation and more effective boundary identification [49]. To solve the image segmentation problem (ISP) for COVID-19 chest X-ray pictures, a unique meta-heuristic method called the slime mould algorithm (SMA) is combined with the whale optimization algorithm to maximize Kapur's entropy. This new hybrid approach is based on the thresholding technique. The experimental findings show that the proposed method outperforms SMA for all the metrics utilized under Kapur's entropy [50]. For the biomedical picture segmentation, a brand-new unsupervised classification method is suggested. The suggested technique is called fuzzy electromagnetic optimization (FEMO) and the ideal clusters may be effectively determined using this method. Results of other quantitative indices are quite encouraging for this approach compared to the other approaches [51]. BMPA is a multi-objective multilevel threshold image segmentation approach based on the boost marine predators' algorithm (BMPA). The findings show that the BMPA outperforms conventional optimization methods in terms of CPU time, peak signal-to-noise ratio and feature similarity. Infrared pictures allow for the accurate detection of insulator flaws in a variety of situations [52]. To address the issues of deep learning model optimization, overfitting and correlation loss optimization in the fine-tuning stage, a medical picture segmentation technique based on positive scaling invariant self-encoding CCA is suggested. The experimental findings reveal that the generated index is significantly enhanced when compared to conventional machine learning techniques [53]. The dimension learning hunting (DLH) is presented together with the conventional operators in an upgraded version of the equilibrium optimizer (EO). Improved Equilibrium Optimizer was its name (I-EO). Results from both quantitative and qualitative research supported the suggested algorithm's superiority over several other well-known optimization techniques. I-EO has been put through trials to deal with real-world applications, and tests have shown that it may be a reliable tool for picture segmentation. [54].

1.3 EARTH AND PLANETARY SCIENCE:

The underutilized modality Synthetic Aperture Radar (SAR) pictures are used to suggest a method for estimating river width which is measured using synthetic aperture radar pictures, which can see through clouds. Furthermore, the SAR photos enable all-weather monitoring of the area and can even capture images at night. U-Net model can divide the crooked riverbanks and little islands [55]. The Landslide Semantic Problem (LSP) is presented as a semantic segmentation problem using optical remote sensing images of landslides. Six popular models are used for LSP, including the Fully Convolutional Network, U-Net, Pyramid Scene Parsing Network, DeepLab v3 and GCN. Six popular semantic segmentation models are used for LSP, including the Fully Convolutional Network, U-Net, Pyramid Scene Parsing Network, Global Convolutional Network (GCN), DeepLab v3 and DeepLab v3+. [56]. MudrockNet is a deep learning SEM image segmentation model built on Google's DeepLab-v3+ architecture and the TensorFlow library. Using trainable Weka segmentation in Image, this model is compared to the random forest classifier, and it was shown that MudrockNet often provided higher predictions for silt grains, clay grains, and pores [57]. An innovative technique for graph-based segmentation of spectral pictures acquired with an Energy Dispersive X-ray Spectroscopy (EDS) detector-equipped Scanning Electron Microscope (SEM) is presented. The technique combines rasterized electron microscopy pictures with sparse EDS samples and deep learning to provide highly effective mineralogy segmentation. These enhanced findings are assessed quantitatively using measurements made with a ground-truth electron microscope and dense, high-count EDS data, as well as visually using a mineralogist's interpretation [58]. An unsupervised method for choosing segmentation parameters is presented that uses local spatial statistics to achieve automatic segmentation parameter optimization. The measurement analysis experiment revealed that BSH is more sensitive to under-segmentation. The multi-resolution segmentation (MRS) approach was used as a segmentation methodology. To determine the overall segmentation quality, two metrics—within-segment homogeneity (WSH) and between-segment heterogeneity (BSH)—were derived using a local spatial statistics approach [59]. Spectral segmentation and integration are a nonparametric, supervised pixel-based feature extraction (FE) technique. It uses the particle swarm optimization (PSO) technique to scan the whole world for the best channel placements and widths. SSI's results were compared to six traditional FE methods, including nonparametric weighted feature extraction and clustering-based features extraction [60]. A unique method with inside the extraction of the feel attributes primarily based totally on the usage of the idea of the HOG is delivered for automated seismic photo segmentation and homes extraction. The proposed method includes extracting the HOG features, deriving statistical parameters associated with the feel attributes and keeping apart the goal via way of means of integrating the chosen images [61]. A technique is put forth to learn evidence in the form of shallow-to-deep visual characteristics, semantic class likelihoods, and class borders. According to the findings, this approach offers superior regularization to a succession of strong baselines that represent cutting-edge technological advancements. The suggested technique provides a flexible and guiding framework to include many sources of visual and structural information [62]. For multiscale segmentation, an adaptive parameter optimization approach is suggested. It seeks to aggregate the best objects from all the findings at all sizes to provide the final segmentation results. The recommended technique is superior to the single scale segmentation result, according to optimization findings over the pictures [63]. Technique combines many segmentations into an optimal segmentation with careful consideration of each item. The framework of object-specific optimization is accomplished by detecting and fusing the relevant nodes in each path emanating from a leaf node. It is based on a segment tree model reflecting hierarchical multiscale segmentations. The advantage of the suggested optimization approach is that it may increase segmentation accuracy [64]. Outcomes show that the segmentation outcomes produced by the suggested scale selection approach are more precise and trustworthy. The band's inverse noise weighting is included in the band's segmentation using an improved approach, and outliers are found and eliminated before the segmentation scale parameters are set. improved approach may be used for different segmentation selection criteria [65].

1.4 BIOCHEMISTRY, GENETICS AND MOLECULAR :

Based on global image information, a better active contour model is presented that can precisely segment images with severe noise and intensity variations. The model is two-phase and multi-phase energy functional and uses them to separate magnetic resonance (MR), ultrasound, and synthetic pictures. Our model has higher accuracy, efficiency, and greater robustness when dealing with impulse and significant noise in image segmentation [66]. The results show that the performance is better in terms of accuracy and time cost. The first module uses K-means clustering to extract the foreground region from the cell picture. Next, touching-cell splitting based on concavity analysis creates a coarse WBC region. A new weak edge enhancement operator that handles fuzzy boundaries and median color characteristics is introduced to increase the segmentation accuracy of the system. The second module actively trains a support vector machine (SVM) classifier using the first module's coarse segmentation results as automated labels. [67]. To diagnose diseases and treat them in clinical settings, automatic medical picture segmentation is a critical diagnostic tool. Convolutional neural networks (CNNs)-based techniques that have recently been presented have shown promise in image processing applications, including several medical image analysis tasks. The sample of small regions of interest is improved (especially in deep layers) and clear global contextual relationships in multi-scale feature spaces are learned. With high percentage sensitivity, the suggested framework provides region performance on the retinal vascular detection job, COVID-19 lung infection segmentation task, and liver tumor segmentation task [68]. Biological cells and organisms depend heavily on cytoskeletal filaments because of their adaptability and the vital roles they play. Most frequently, these biopolymers are arranged into intricately shaped scaffolds that resemble networks. These networks' geometrical and topological architecture may be used to gain important understanding of how they function. Exact segmentation of microscopic images is required for the accurate study of the network structure and connectivity. In biomedical imaging, where tracing of blood vessels and neurons is common, segmentation of filament-like objects is a well-studied topic [69].

1.5 AGRICULTURE AND BIOLOGICAL SCIENCE:

A well-known technique for extracting object segments from photos is the Multiresolution Segmentation (MRS) algorithm. Knowing which size, shape, and compactness variables to employ beforehand determines the quality of segmentation. This method is based on Bayesian optimization, a sequential model-based optimization (SMBO) technique for maximizing or minimizing an objective function. To determine how comparable segmented agricultural products and their respective reference parcels are, it maximized the Jaccard index. The relationship between the size of agricultural units and segmentation quality [70]. For infield picture segmentation, the varying lighting and weather conditions present significant challenges. To get accurate image segmentation results, strong, quick, and automated techniques are crucial. The goal of this study was to create effective unsupervised clustering algorithms for in-field oilseed rape image segmentation. Finally, computation time and image segmentation quality were used to gauge how well the algorithms performed. All clustering techniques have been shown to be resilient to changing lighting conditions and are capable of processing photos with extremely complicated backgrounds automatically. By merging the top color features retrieved from ten different color spaces, the segmentation accuracy was significantly increased. [71]. This study develops and publicly shares labelled data, as well as a trained deep learning model, for irrigation type segmentation that can be applied/transferred to other regions globally. It also uses deep learning and remote sensing to solve the long-standing real-world problem of multiple irrigation type segmentation. The paper also provides fresh insights into the effects of transfer learning, imbalanced training data, and the effectiveness of different model topologies for multiple irrigation type segmentation. Applying very high-resolution remote sensing images, such as those from commercial satellites, the suggested deep segmentation model can categories a variety of irrigation systems at regional to global sizes [72]. Convex hull center priori and Markov adsorption chain-based is used for apple picture segmentation. Finally, an Otsu algorithm threshold was employed to adaptively segment the prominent portion of an apple image. The results for the saliency target detection algorithm for the segmentation of apple images are promising. This experiment demonstrates that, even with some of the apple's features being only partially segmented, the operational results and efficiency are optimal [73]. An effective and non-destructive tool for analyzing leaf chlorophyll content (LCC) and crop growth status is provided by hyperspectral imaging (HSI) technology. The results indicate that the best estimation result with the best soil background removal performance was obtained by soil-adjusted vegetation index (SAVI) segmentation. After using canopy segmentation, K-means clustering was used to separate the pixel-level wheat canopy spectrum into clusters. The ability to minimize the effects of canopy complexity was demonstrated by the spectra clusters. There is a resulted spectra cluster created using SAVI picture segmentation helped to improve LCC estimate. [74] This study examines the segmentation of butterflies in ecological photos that contain a variety of artefacts, such as intricate environmental decorations and crowded backdrops. The numerous distractions present in the diverse natural milieu and the stark distinctions across butterfly species make segmentation a difficult operation. Then, to enhance the quality of segmentation, carry out a graph ranking procedure with high level guidance based on foreground and background cues. A weighting system that effectively blends color, texture, and spatial information improves ranking accuracy, then, to extract the butterfly from the background, establish foreground seeds from the highest significant pixels and background seeds from the less relevant pixels as an input for a Graph-cut method. [75]. A system for the segmentation and classifying of sunflower leaf images is presented. It uses The Particle Swarm Optimization technique to segment sunflower leaf pictures, which is a crucial step in the disease classification process. It has been effective at identifying and categorizing disorders. It clearly demonstrates the effectiveness of the suggested algorithm in identifying and categorizing illnesses of sunflower leaf [76].

1.6 NEUROSCIENCE:

A robust and quick segmentation method called the Active Contour Model (ACM) is introduced. The computational cost of this approach is significantly lower than the bias correction model. It is powered by pre-fitting bias correction and an improved fuzzy c-means (FCM) algorithm. The suggested model can efficiently segment pictures with severe intensity inhomogeneity, according to tests on actual and synthetic images [77]. For multimodal medical picture segmentation, a multi-scale context-aware network (CA-Net) is suggested that collects rich contextual information with dense skip connections and gives varying weights to various channels. Four essential parts make up CA-Net: an encoder module, a decoder module, a multi-scale context fusion (MCF) module, and a dense skip connection module [78]. For the goal of segmenting medical images, a scalable functional variational Bayesian neural network (BNN) containing Gaussian processes (GPs) is presented. With just one forward pass, our approach can conduct predictive inference and facilitate effective training. Numerous segmentation datasets are used in the trials, and the findings show that the suggested methodology performs better than numerous state-of-the-art approaches in terms of segmentation performance metrics and uncertainty estimations [79]. A weak fuzzy partition-based segmentation technique is provided. To build a generalized fuzzy complement, first a technique is presented. Then go on to build a generalized fuzzy complement operator, which has a great feature for parameter optimization in practical applications. A weak fuzzy partition entropy-based picture segmentation technique is suggested using these ideas. For noisy pictures, the suggested 2D weak fuzzy partition entropy-based technique performs particularly well [80]. AdaResU-Net, a multi-objective adaptive convolutional neural network, is introduced for segmenting medical images and can automatically adapt to new datasets while maintaining a small network size. The AdaResU-Net achieves improved segmentation performance of trainable parameters, according to the results [81]. Based on the energy functional similarity measure, an analysis of regional level set image segmentation models is presented. It starts out with a description of region-based level set image segmentation's basic processes. The various segmentation models are then briefly discussed [82]. It was suggested to use a Multi-view Attention Super Pixel-guided Generative Adversarial Network (MASG-GAN) to accomplish multi-task learning for tissue categorization and nuclei segmentation. In more detail, the teacher branch directs the student branch for precise segmentation and classification using a super pixel-prior probability map as input. To further improve the segmentation quality of nuclei with tiny area and unclear border, a Multi-view Attention Module (MVAM) is created [83]. To produce adversarial instances for medical image segmentation models, a differential evolution attack (DEAttack) strategy is suggested. The suggested technique outperforms gradient-based methods in effectively attacking the segmentation model with only a tiny proportion of the image pixels perturbed, suggesting that the medical image segmentation model is more vulnerable to adversarial cases [84]. To solve the problem of time-consuming iterative image registration utilized for atlas warping, a novel framework of One-pass aligned Atlas Set for Images Segmentation (OASIS) is introduced. The suggested technique takes advantage of the capabilities of deep learning to accomplish one-pass picture registration. Furthermore, by using label constraints, OASIS directs the registration process to the regions to be segmented, boosting segmentation performance [85]. To solve the medical domain mismatch problem, a novel unsupervised domain adaptation paradigm called Collaborative Appearance and Semantic Adaptation (CASA) is developed. This approach could use a Characterization Transfer Module (CTM) to convert the look of medical lesions between domains, which might help to reduce the appearance divergence of medical lesions across domains [86]. A new excitation-based CNN is proposed by adaptively recalibrating network functions to improve bone segmentation by segmenting magnetic resonance (MR) images of the brain into three tissue classes: bone, soft tissue, and air. The two blocks are sequentially combined and seamlessly integrated into a 3D convolutional encoder-decoder network. The novel idea arises from sequentially combining the two excitation blocks to improve segmentation performance and reduce model complexity. This segmentation network architecture shows promising and competitive results compared to other methods in the literature and reduces the complexity of the model thanks to the sequential combination of the two excitation blocks [87]. For adversarial learning, a novel asymmetric semi-supervised GAN (ASSGAN) with two generators and a discriminator is suggested. The two generators may supervise each other, generating reliable segmentation predicted masks as advice for each other in the absence of labels. The experimental findings demonstrate that the suggested strategy performs well even when there are a limited number of tagged photos [88]. To obtain more accurate medical picture segmentation, x-Net, a novel deep model, is presented. x-advancements Nets are mostly threefold: First, it integrates an additional expanding channel into U-Net to import an additional supervision signal and achieve a more efficient and stable picture segmentation via dual supervision. The three proposed advances are all effective and essential for x-Net to achieve superior performance, and the proposed multi-dimensional self-care is more effective than state-of-the-art care mechanisms (or multi-scale solutions) for medical imaging segmentations [89]. Knowledge Distillation from Multi-head Instructor (KDM) is a novel framework that distils the knowledge of a multi-head teacher to the learner. Our suggested KDM aids the learning of a very capable student while greatly reducing training time by encapsulating several teachers in a single network. When tested on this dataset, the student trained using KDM has many orders of magnitude less parameters than the state-of-the-art segmentation model (i.e., HRNet), while attaining competitive accuracy [90]. A unique extended hidden Markov model (EHMM) for optimal breast thermogram segmentation was reported, allowing for more effective picture interpretation and simpler analysis of Infrared (IR) thermal patterns. This method has a competitive advantage in that it handles random sampling of breast IR images with re-estimation of model parameters. It is worth mentioning that the given approach can considerably map semi-hot regions into distinct areas and extract the regions of breast thermal pictures while reducing execution time [91].

1.7 PHYSICS AND ASTRONOMY:

A new evaluation criterion primarily based totally at the Gini index and the estimation of entropy. Benchmark pics segmented the use of the multilevel thresholding method primarily based totally on particle swarm optimization are applied in trials to decide the strength, efficacy, and velocity of the proposed evaluation criterion [92]. Based on the usual Chan-Vese version, a unique variational version for photograph segmentation turned into offered. Then, for numerical implementation, we examine the theoretical solvability of the brand-new version and construct a brand-new approach primarily based totally on the Split Bregman algorithm. Finally, we carry out segmentation research on grayscale pics and evaluate the consequences to the traditional Chan-Vese version. The accrued findings exhibit numerous benefits of this method with several applications [93]. A biomedical sensor photographs segmentation method primarily based totally on an upgraded completely convolutional community is described. The version can take away the phenomena of molecular attachment after photograph segmentation, has a higher segmentation impact and accuracy, and may make higher use of pics recorded via way of means of biomedical sensors [94]. To focus on growing the top-rated segmentation version that meets excessive metrics and is immune to microscope settings. The models' generalizability turned into examined the use of E-TEM Gold nanoparticle pics. When choosing a community for segmenting nanoparticle pics, numerous issues had been discussed. To higher spotlight the black-container thing of neural networks, the layer gradients are shown [95]. From this entropy carried out to multi-threshold segmentation of scientific pics, seven of the maximum promising bio-stimulated algorithms had been advised. The findings illustrate the variety of values of Tsallis entropy's so known as non-extensivity parameter. It is likewise proved that the Firefly algorithm (FFA) achieves the first-rate segmentation overall performance, even as the Grey Wolf Optimizer (GWO) executed the quickest convergence [96]. A precise context touchy power curve primarily based totally Masi entropy for photograph segmentation using the moth swarm algorithm (MSA) is advised. It is a newly designed stochastic meta-heuristic optimization approach that turned into delivered via way of means of watching, replicating, and modelling the moth swarm existence cycle. It is used to lessen the undertaking of prolonged exploration to perceive the first-rate threshold values and enhance photograph excellent. It has an extra overall performance in phrases of threshold excellent and a discounted computational cost [97]. Infrared thermal imaging (IRT) electric photographs are received to diagnose defects via the method of photograph pre-processing and segmentation. First, the IRT photographs are transformed to a grayscale photograph, accompanied via way of means of photograph pre-processing in which histogram equalization is carried out. To optimize the middle of gravity of the

FCM algorithm, the changed Ant Lion optimization (BAD) is proposed. This method can take away remote pixels from the photograph and extract photograph additives to render photographs higher [98]. A photograph segmentation approach primarily based totally on fractional Darwin particle swarm optimization algorithm (FODPSO) is used to reconstruct infrared photograph sequences to resolve the troubles of excessive noise and fuzzy edges of received infrared photographs whilst detecting debonding faulty additives of SiC thermal barrier coating shape via way of means of pulsed infrared thermal waves. The experimental findings exhibit that the FODPSO approach effectively overcomes the drawbacks of preceding algorithms, along with smooth access of nearby top-rated and slow convergence time and may locate SiC coating flaws at the threshold [99]. For the deteriorated IR spectrum attributable to overlap and noise degradation, a resolution-enhancement approach with overall version (TV-norm) necessities turned into devised. The infrared spectrometer equipment and Fourier-optical idea are used to calculate the factor unfold feature. It can estimate the factor unfold feature simultaneously via way of means of introducing adaptive overall version and constraint regularization [100]. For infrared photograph segmentation, a completely unique convolutional neural community turned into offered that may resolve the problems of movement blur, low resolution, and random noise. We advised a unique loss feature that contains the shape, area, and centroid right into a fundamental deep mastering version all through mastering. The R-Net outperforms the present infrared photograph segmentation techniques in experiments [101]. For thermal photograph segmentation, a multi-stage pixel spatial interest community turned into developed. On every tier of the spine community (MPAM), a pixel area interest module turned into constructed to get better extra spatial element even as preserving extra semantic information. Then we created an area extraction module (EEM) and a small goal extraction module (STEM) that enhance the community's area and small goal capabilities via way of means of explicitly modelling the threshold and small goal characteristics [102].

1.8 Materials Science:

To estimate cement fragment distributions, a holistically nested convolutional network (HCN) and associated morphological analyses are explored. The segmentation and size calculation accomplished using our approach were superior to those utilizing comparable conventional techniques, according to experimental data [103]. CNN has been tested for its ability to partition concrete data without relying on color. It showed a significant ability to process a variety of concretes. According to the experimental findings, CNN performs far better than human segmentation. In addition, segmentation takes only a few seconds and reveals significant information [104]. Deep learning-based image segmentation technique to process mineral image masks and segment the important regions in mineral images. The experiment's findings demonstrate the good segmentation performance of the suggested mineral image segmentation model. We compare the training performance of CNN-based models under various loss functions and suggest a new loss function appropriate for mineral picture segmentation [105]. An advantageous method for maintaining roads could be the quick detection of early pavement deterioration. Early fracture detection enables the adoption of protective measures to avert damage and potential failure. With the development of computer vision and image processing, semi-automatic/automatic procedures have supplanted traditional visual inspection in the field of civil engineering. The recognition of slender, uneven black lines hidden by textured backdrops is the main difficulty in pavement picture segmentation. The academic community is actively working on image-based identification of pavement cracks. It places a strong emphasis on the three main categories of methods used in the field of image segmentation [106]. Diverging artefacts, comparable breast tissues and decreased contrast are the main problems with mammograms' ability to predict breast cancer. The Optimized Kernel Fuzzy Clustering Algorithm (OKFCA) was created to identify cancerous areas in mammography pictures. Mammogram Image Analysis Society (MIAS) database has segmented zones that can be identified using the OKFCA technique. MIAS OKFCA is a significant method for identifying the cancer segment of the mammography image. The Hybrid Denoising Filter (HDF) technique was used to generate a noise-free image. Results of the trials conducted on the MIAS data show that the suggested system is more accurate and efficient [107]. For numerous applications involving photo handling, numerous streamlining techniques have been put forth. This includes Firefly calculation, Differential development, Particle swarm enhancement, Genetic calculation, and Artificial honeybee state advancement. The results are compared with entropy techniques for Shannon or Fuzzy. Additionally, it expands picture splitting, rebuilding, edge recognition, upgrading, acknowledging picture designs, picture age, thresholding, combining pictures, and so forth [108]. The K-Means technique is used in this work to segment images. It allows for the determination of specific images and groupings of photos. When the photos are converted to grey scale, it makes it easier to extract clusters. The correlation of the image's available pixels is what allows for object discrimination [109]. A little contribution is made to the monumental effort of preserving the tigers as a species. The conservation of tiger reserves has been the subject of inquiry by numerous scientists. Techniques for picture classification and clustering based on color pixels have been utilized to determine the tiger's age. Image filtering and enhancement techniques are used to reduce noise and improve the quality of pixels or images. The computation time, retrieval time, accuracy, and error rate of the research work are evaluated by generating better results in the real-time tiger image database [110]. Electromagnetism Optimization (EMO) is the primary multilevel thresholding technique used in Otsu's work. The extraction of transition regions for picture segmentation is proposed using a clustering methodology. When comparing approaches based on the picture histogram to those using EMO on energy curve, the latter method produces better results. [111]. A method for extracting transition regions based on a clustering approach to image segmentation has been proposed. In addition, the Otsu threshold is applied to the transition feature image to extract the transition region. To extract the exact edge image, a morphological thinning operation is performed. The area fills and morph cleanup operation is performed on an edge image to preserve the areas of the object. This method is compared with different image segmentation methods. An experimental result shows that the proposed method outperforms other methods for segmenting images containing one or more objects [112].

1.9 ENVIRONMENTAL SCIENCE:

A hierarchical method for automated segmentation is suggested which is based on Gaussian process regression and Kernel Linear Discriminant Analysis (KLDA). In the first level, KLDA is used to distinguish the target leaf from its backdrop of similar leaves in two steps. The edge detection and morphological processes required for producing the fine segmented image are applied at a second level. It is suggested to apply the Gaussian-based regression technique to estimate the tuning parameters needed for morphological processing to fully automate the segmentation process. [113]. Study of accurate boundary recovery for semantic segmentation. Focus is on 2D pictures and 3D point clouds, with a primary focus on DCNNs. It examines how boundary recovery approaches generate precise semantic segmentation borders by classifying them into four strategies based on their methodology and network designs [114]. High resolution change detector (HRCD) DeepLab is created. A framework (MaskNet) based on masks is introduced, which updates model parameters using a few annotated samples. To fully utilize HR, we created a Mask-DeepLab based on MaskNet. The experiment results' visualization and quantitative analysis indicate that this algorithm can implement a significant performance improvement. First, a framework (MaskNet) based on masks is introduced, which updates model parameters using a few annotated samples [115]. The deep neural network AQUANet outperforms other semantic segmentation networks on a huge waterbody image dataset called ATLANTIS, according to experimental results. The deep neural network is created by analyzing the aquatic and non-aquatic regions of waterbodies in two separate routes. It also uses cross-path modulation and low-level feature-modulation to improve feature representation [116]. A new network called Ice-Deeplab for pixel-wise ice picture segmentation is proposed. Deeplab deep convolutional neural network is used to build the Ice-Deeblab network, which has been enhanced with an attention module and a better decoding structure. The proposed model produces better segmentation results than the original Deeplab model, achieving a high accuracy among the classes' sea-ice, ocean, and sky [117]. To solve the over-segmentation issue of organisms with complex structures such as jellyfish, we used a 2-stage adaptive binarization algorithm. Jellyfish have a somewhat complicated structure and are frequently over-sauvaged. Results revealed that the method, when compared to conventional binarization techniques, increased the quality of extracted jellyfish and increased hardware resource consumption and computational efficiency. Results revealed that the method, when compared to conventional binarization techniques, increased the quality of extracted jellyfish and increased hardware resource consumption [118].

2. FOUNDATIONS OF IMAGE SEGMENTATION:

Segmentation techniques are frequently categorized into three categories:

2.1 Pixel-Based Image Segmentation:

It mostly consists of thresholding and clustering techniques. The actual segmentation results are quite sloppy because thresholding methods significantly rely on the number of thresholds and the variable choices. Because they are more robust than thresholding procedures, clustering algorithms are more popular. Hierarchical clustering, c-means clustering, fuzzy c-means clustering, density clustering, and spectral clustering are the basic clustering techniques. The hierarchical clustering technique achieves hierarchical decomposition by using pixel similarity. Although this type of algorithm is straightforward and simple to use, the resulting segmentation outcomes depend on the creation of the tree and the choice of the threshold; as a result, hierarchical clustering-based image segmentation techniques are uncommon. Recent years have seen the emergence of a model clustering concept known as "density clustering," which classifies the data by considering the spatial distribution structure of all samples, particularly their density. It categorizes the data by taking into consideration the geographic distribution structure of all samples, particularly their density, has emerged in recent years. The initial clustering center is chosen for density clustering based on the varied sample densities, and the cluster is subsequently updated depending on the associations between the samples.

2.2 Contour-Based Image Segmentation:

By looking for the edge of each section in a picture, contour-based image segmentation aims to achieve image segmentation. This kind of approach was first based mostly on image gradient computation, such as the well-known Sobel, Robert, and Canny operators. The gradient in the image cannot easily be converted into a closed contour. Since there are various task requirements, we often employ a threshold method in traditional edge detection to get results for contour detection. A level set method is used to depict the geometric active contour model. A digital technique called level set is used to monitor surface and contour motion. It also known as the level set function, sets the contour as a zero-level set of a high-dimensional function rather than operating the contour directly. The motion's contour is then produced by removing the zero-level set from the output of this function after it has been differentiated. The level set's key benefit is the ability to model and topologically transform any complex structure.

2.3 Region-Based Image Segmentation:

The seeds are first initialized in region-based image segmentation, which then seeks out roughly comparable pixels (which are typically treated as a class) and updates the seeds until convergence is attained. Region expanding, region splitting and merging, and superpixel are the three basic techniques for region-based picture segmentation. These techniques rely on the outcomes of superpixel segmentation. SLIC, turbopixel, DBSCAN, LSC, DEL, GMM, and ISF are some of the popular superpixel algorithms. To achieve superpixel segmentation, the majority of these superpixel algorithms use the contour iterative optimization technique in a local grid. These algorithms' benefits include the ability to produce superpixel segmentation results based on a predetermined number of areas, which can produce more precise local grid borders. Due to the lack of global information, the optimization technique only functions in the local grid, which makes it challenging to capture the true object contour.

3. IMAGE SEGMENTATION EVALUATION:

The evaluation indexes primarily depend on error rate, segmentation contour quality, region quality, and other parameters to mimic human visual perception.

3.1 Accuracy evaluation index:

3.1.1 Pixel Accuracy (PA):

It is simply calculated as the proportion of correctly categorized pixels to all pixels.

3.1.2 Mean Pixel Accuracy (MPA):

By calculating the percentage of correctly categorized pixels inside each class and averaging the correct rate across all classes, MPA is an expanded version of PA.

3.1.3 Precision/Recall/F1 score:

Because the traditional image segmentation algorithms frequently use Precision/Recall/F1 score, these metrics are well-liked.

3.2 Regional quality evaluation index

3.2.1 Dice coefficient:

It is another widely used measure for image segmentation, which is more frequently applied to medical image analysis. Its definition is the overlap area between predicted and ground-truth maps divided by the sum of all pixels in both images.

3.2.2 Intersection Over Union (IOU):

It is one of the most well-liked metrics in semantic segmentation, also known as the Jaccard index. It is determined by dividing the region of intersection between the anticipated segmentation map and the ground truth by the area of union between the two.

3.2.3 Volume Overlap Error (VOE):

It is the Jaccard index's complement.

3.2.4 Relative Volume Difference (RVD):

It is an asymmetric measurement.

3.3 Contour quality evaluation index:

3.3.1 Hausdorff distance (HD):

It is a metric that quantifies how similar two sets of points are to one another.

3.3.2 Average symmetric surface distance (ASD)

3.3.3 Maximum symmetric surface distance (MSD):

Like ASD but using the maximum distance rather than the average, it is also known as the symmetric Hausdorff distance.

4. CONCLUSIONS AND FUTURE WORK

Due to the urgent need to transfer images with large size through internet networking without losing image accuracy, a new technique should be presented. Image segmentation without losing image details and accuracy is urgent and required, especially in the medical field. Optimization techniques are implemented for image segmentation in many fields. This study implements a hybrid optimization technique for image segmentation without losing image accuracy. Different techniques can be used for developing the study goal.

REFERENCES

[1] Hang Su, Dong Zhao, Hela Elmannai, Ali Asghar Heidari, Sami Bourouis, Zongda Wu, Zhennao Cai, Wenyong Gui , Mayun Chen , “Multilevel threshold image segmentation for COVID-19 chest radiography: A framework using horizontal and vertical multiverse optimization”, Computers in Biology and Medicine 146 (2022) 105618.

[2] Songwei Zhao, Pengjun Wang, Ali Asghar Heidari, Huiling Chen, Wenming He, Suling Xu, “Performance optimization of salp swarm algorithm for multi-threshold image segmentation”, Computers in Biology and Medicine 139 (2021) 105015.

[3] Songwei Zhao, Pengjun Wang, Ali Asghar Heidari, Huiling Chen, Hamza Turabieh, Majdi Mafarja, Chengye Li, “Multilevel threshold image segmentation with diffusion association slime mould algorithm and Renyi’s entropy for chronic obstructive pulmonary disease”, Computers in Biology and Medicine 134 (2021) 104427

[4] Lei Liu, Dong Zhao, Fanhua Yu, Ali Asghar Heidari, Chengye Li, Jinsheng Ouyang, Huiling Chen, Majdi Mafarja, Hamza Turabieh, Jingye Pan, “Ant colony optimization with Cauchy and greedy Levy mutations for multilevel COVID 19 X-ray image segmentation”, Computers in Biology and Medicine, 136 (2021) 104609

[5] Lei Liu, Dong Zhao, Fanhua Yu, Ali Asghar Heidari, Jintao Ru, Huiling Chen, Majdi Mafarja, Hamza Turabieh, Zhifang Pan, “Performance optimization of differential evolution with slime mould algorithm for multilevel breast cancer image segmentation”, Computers in Biology and Medicine, 138 (2021) 104910

[6] Qian Zhang, Zhiyan Wang, Ali Asghar Heidari, Wenyong Gui, Qike Shao, Huiling Chen, Atef Zaguia, Hamza Turabieh, Mayun Chen, “Gaussian Barebone Salp Swarm Algorithm with Stochastic Fractal Search for medical image segmentation: A COVID-19 case study”, Computers in Biology and Medicine, 139 (2021) 104941

[7] Sanjoy Chakraborty, Apu Kumar Saha, Sukanta Nama, Sudhan Debnath, “COVID-19 X-ray image segmentation by modified whale optimization algorithm with population reduction”, Computers in Biology and Medicine, 139 (2021) 104984

[8] Xiaowei Chen, Hui Huang, Ali Asghar Heidari, Chuanyin Sun, Yinqiu Lv, Wenyong Gui, Guoxi Liang, Zhiyang Gu, Huiling Chen, Chengye Li, Peirong Chen, “An efficient multilevel thresholding image segmentation method based on the slime mould algorithm with bee foraging mechanism: A real case with lupus nephritis images”, Computers in Biology and Medicine, 142 (2022) 105179

[9] Hang Su, Dong Zhao, Fanhua Yu, Ali Asghar Heidari, Yu Zhang, Huiling Chen, Chengye Li, Jingye Pan, Shichao Quan, “Horizontal and vertical search artificial bee colony for image segmentation of COVID-19 X-ray images”, Computers in Biology and Medicine, 142 (2022) 105181

[10] Rabindra Khadka, Debesh Jha, Steven Hicks, Vajira Thambawita, Michael A. Riegler, Sharib Ali, Pål Halvorsen, “Meta-learning with implicit gradients in a few-shot setting for medical image segmentation”, Computers in Biology and Medicine, 143 (2022) 105227

[11] Li Zhu, Qiong He, Yue Huang, Zihe Zhang, Jiaming Zeng, Ling Lu, Weiming Kong, Fuqing Zhou, “DualMMP-GAN: Dual-scale multi-modality perceptual generative adversarial network for medical image segmentation”, Computers in Biology and Medicine, 144 (2022) 105387

[12] Zhongxi Qiu, Yan Hu, Jiayi Zhang, Xiaoshan Chen, Jiang Liu, "FGAM: A pluggable light-weight attention module for medical image segmentation", Computers in Biology and Medicine, 146 (2022) 105628
[13] Chengtao Peng, Yue Zhang, You Meng, Yang Yang, Bensheng Qiu, Yuzhu Cao, Jian Zheng, "LMA-Net: A lesion morphology aware network for medical image segmentation towards breast tumors", Computers in Biology and Medicine, 147 (2022) 105685
[14] Krishna Chaitanya, Neerav Karani, Christian F. Baumgartner, Ertunc Erdil, Anton Becker, Olivio Donati, Ender Konukoglua, "Semi-supervised task-driven data augmentation for medical image segmentation", Medical Image Analysis, 68 (2021) 101934
[15] Shuai Chena, Zahra Sedghi Gamechi, Florian Dubost, Gijs van Tulder, Marleen de Bruijnea, "An end-to-end approach to segmentation in medical images with CNN and posterior-CRF", Medical Image Analysis, 76 (2022) 102311
[16] Abdenour Mekhmoukh, Karim Mokrani, "Improved Fuzzy C-Means based Particle Swarm Optimization (PSO) initialization and outlier rejection with level set methods for MR brain image segmentation", computer methods and programs in biomedicine 122 (2015) 266–281
[17] Zihao Wanga, Thomas Demarcy, Clair Vandersteena, Dan Gnansia, Charles Raffaelli, Nicolas Guevara, Hervé Delingettea, "Bayesian logistic shape model inference: Application to cochlear image segmentation", Medical Image Analysis, 75 (2022) 102268
[18] Xin Yan, Guirong Weng, "Hybrid active contour model driven by optimized local pre-fitting image energy for fast image segmentation", Applied Mathematical Modelling, 101 (2022) 586–599
[19] Xinyu Zhang, Guirong Weng, "Level set evolution driven by optimized area energy term for image segmentation", Optik, 168 (2018) 517–532
[20] Shuai Luoa, Yujie Li, Pengxiang Gao, Yichuan Wang, Seiichi Serikawa, "Meta-seg: A survey of meta-learning for image segmentation", Pattern Recognition, 126 (2022) 108586
[21] Yuzhen Lu, Sierra Young, Haifeng Wang, Nuwan Wijewardane, "Robust plant segmentation of color images based on image contrast optimization", Computers and Electronics in Agriculture, 193 (2022) 106711
[22] Hao Wu, Zhenjiang Miao, Jingyue Chen, Qiang Zhang, Wuran Xu, Tianyu Zhou, "Optimized image segmentation based on OLS operator", Optik, 126 (2015) 305–308
[23] Haiyang Li ∗, Hongzhou He, Yongge Wen, "Dynamic particle swarm optimization and K-means clustering algorithm for image segmentation", Optik, 126 (2015) 4817–4822
[24] Hao Wu, Rongfang Bie, Junqi Guo, Xin Meng, Chenyun Zhang, "CNN refinement-based object recognition through optimized segmentation", Optik, 150 (2017) 76–82
[25] Mohamed Abd Elaziz, Dalia Yousri, Mohammed A.A. Al-qaness, Amr M. AbdelAty, Ahmed G. Radwan, Ahmed A. Ewees g,h , "A Grunwald–Letnikov based Manta ray foraging optimizer for global optimization and image segmentation", Engineering Applications of Artificial Intelligence 98 (2021) 104105.
[26] Nand Kishor Yadav, Mukesh Saraswat, "A novel fuzzy clustering-based method for image segmentation in RGB-D images", Engineering Applications of Artificial Intelligence 111 (2022) 104709
[27] Inès Hilali-Jaghdam, Anis Ben Ishak, S. Abdel-Khalek, Amani Jamal, "Quantum and classical genetic algorithms for multilevel segmentation of medical images: A comparative study", Computer Communications, 162 (2020) 83–93
[28] R. Radha, R. Gopalakrishnan, "A medical analytical system using intelligent fuzzy level set brain image segmentation based on improved quantum particle swarm optimization", Microprocessors and Microsystems, 79 (2020) 103283
[29] Shilpa Suresh, Shyam Lal, "Multilevel thresholding based on Chaotic Darwinian Particle Swarm Optimization for segmentation of satellite images", Applied Soft Computing, 55 (2017) 503–522
[30] Xinming Zhang, Shaochen Wen, Doudou Wang, "Multi-population biogeography-based optimization algorithm and its application to image segmentation", Applied Soft Computing, 124 (2022) 109005
[31] Keyan Ding, Linfang Xiao, Guirong Wenga, "Active contours driven by region-scalable fitting and optimized Laplacian of Gaussian energy for image segmentation", Signal Processing, 134 (2017) 224–233
[32] Priyambada Subudhi, Susanta Mukhopadhyay, "A statistical active contour model for interactive clutter image segmentation using graph cut optimization", Signal Processing, 184 (2021) 108056

[33] Y. Nagaraj, Pardhu Madipalli, Jeny Rajan, P. Krishna Kumar, A.V. Narasimhadhan, “Segmentation of intima media complex from carotid ultrasound images using wind driven optimization technique”, Biomedical Signal Processing and Control, 40 (2018) 462–472

[34] Guowei Wang, Shuli Guo, Lina Han, Anil Baris Cekderi, “Two-dimensional reciprocal cross entropy multi-threshold combined with improved firefly algorithm for lung parenchyma segmentation of COVID-19 CT image”, Biomedical Signal Processing and Control, 78 (2022) 103933

[35] Sowjanya Kotte, Rajesh Kumar Pullakura, Satish Kumar Injeti, “Optimal multilevel thresholding selection for brain MRI image segmentation based on adaptive wind driven optimization”, Measurement, 130 (2018) 340–361

[36] Lili Ren, Ali Asghar Heidari, Zhennao Cai, Qike Shao, Guoxi Liang, Hui-Ling Chen, Zhifang Pan, “Gaussian kernel probability-driven slime mould algorithm with new movement mechanism for multi-level image segmentation”, Measurement, 192 (2022) 110884

[37] Zhikai Xing, “An improved emperor penguin optimization based multilevel thresholding for color image segmentation”, Knowledge-Based Systems, 194 (2020) 105570

[38] Dalia Yousri, Mohamed Abd Elaziz, Seyedali Mirjalili, “Fractional-order calculus-based flower pollination algorithm with local search for global optimization and image segmentation”, Knowledge-Based Systems, 197 (2020) 105889

[39] Dong Zhao, Lei Liu, Fanhua Yu, Ali Asghar Heidari, Mingjing Wang, Guoxi Liang, Khan Muhammad, Huiling Chen, “Chaotic random spare ant colony optimization for multi-threshold image segmentation of 2D Kapur entropy”, Knowledge-Based Systems, 216 (2021) 106510

[40] Essam H. Houssein, Kashif Hussain, Laith Abualigah, Mohamed Abd Elaziz, Waleed Alomoush, Gaurav Dhiman, Youcef Djenouri, Erik Cuevas, “An improved opposition-based marine predators’ algorithm for global optimization and multilevel thresholding image segmentation”, Knowledge-Based Systems, 229 (2021) 107348

[41] Helong Yu, Jiuman Song, Chengcheng Chen, Ali Asghar Heidari, Jiawen Liu, Huiling Chen, Atef Zaguia, Majdi Mafarja, “Image segmentation of Leaf Spot Diseases on Maize using multi-stage Cauchy-enabled grey wolf algorithm”, Engineering Applications of Artificial Intelligence, 109 (2022) 104653

[42] Guoyuan Ma, Xiaofeng Yue, “An improved whale optimization algorithm based on multilevel threshold image segmentation using the Otsu method”, Engineering Applications of Artificial Intelligence, 113 (2022) 104960

[43] Xiaolin Tian, Licheng Jiao, Long Yi, Kaiwu Guo, Xiaohua Zhang, “The image segmentation based on optimized spatial feature of superpixel”, J. Vis. Commun. Image R., 26 (2015) 146–160

[44] Rosana El Jurdi, Caroline Petitjean, Paul Honeine, Veronika Cheplygina, Fahed Abdallah, “High-level prior-based loss functions for medical image segmentation: A survey”, Computer Vision and Image Understanding, 210 (2021) 103248

[45] Rasmiranjan Mohakud, Rajashree Dash, “Skin cancer image segmentation utilizing a novel EN-GWO based hyper-parameter optimized FCEDN”, Journal of King Saud University – Computer and Information Sciences, xxx (xxxx) xxx

[46] Tahir Sag˘, Mehmet C¸ unkas¸, “Color image segmentation based on multiobjective artificial bee colony optimization”, Applied Soft Computing, 34 (2015) 389–401

[47] Xiaoli Zhao, Matthew Turk, Wei Li, Kuo-chin Lien, Guozhong Wang, “A multilevel image thresholding segmentation algorithm based on two-dimensional K–L divergence and modified particle swarm optimization”, Applied Soft Computing, 48 (2016) 151–159

[48] Anitha Vishnuvarthanan, M. Pallikonda Rajasekaran, Vishnuvarthanan Govindaraj, Yudong Zhang, Arunprasath Thiyagarajan, “An automated hybrid approach using clustering and nature inspired optimization technique for improved tumor and tissue segmentation in magnetic resonance brain images”, Applied Soft Computing, 57 (2017) 399–426

[49] Yongsheng Pan, Yong Xia, Tao Zhou, Michael Fulham, “Cell image segmentation using bacterial foraging optimization”, Applied Soft Computing, 58 (2017) 770–782

[50] Mohamed Abdel-Basset, Victor Chang, Reda Mohamed, “HSMA_WOA: A hybrid novel Slime mould algorithm with whale optimization algorithm for tackling the image segmentation problem of chest X-ray images”, Applied Soft Computing Journal, 95 (2020) 106642

[51] Shouvik Chakraborty, Kalyani Mali, “Fuzzy Electromagnetism Optimization (FEMO) and its application in biomedical image segmentation”, Applied Soft Computing Journal, 97 (2020) 106800
[52] Zhikai Xing, Yigang He, “Many-objective multilevel thresholding image segmentation for infrared images of power equipment with boost marine predators’ algorithm”, Applied Soft Computing, 113 (2021) 107905
[53] Feng-Ping An, Jun-e Liu, Jian-rong Wang, “Medical image segmentation algorithm based on positive scaling invariant-self encoding CCA”, Biomedical Signal Processing and Control, 66 (2021) 102395
[54] Essam H. Houssein, Bahaa El-din Helmy, Diego Oliva, Pradeep Jangir, M. Premkumar, Ahmed A. Elngar, Hassan Shaban, “An efficient multi-thresholding based COVID-19 CT images segmentation approach using an improved equilibrium optimizer”, Biomedical Signal Processing and Control, 73 (2022) 103401
[55] Ujjwal Verma, Arjun Chauhan, Manohara Pai M.M., Radhika Pai, “DeepRivWidth: Deep learning based semantic segmentation approach for river identification and width measurement in SAR images of Coastal Karnataka”, Computers & Geosciences, 154 (2021) 104805
[56] Bowen Du, Zirong Zhao, Xiao Hu, Guanghui Wu, Liangzhe Han, Leilei Sun, Qiang Gao, “Landslide susceptibility prediction based on image semantic segmentation”, Computers & Geosciences, 155 (2021) 104860
[57] Abhishek Bihani, Hugh Daigle, Javier E. Santos, Christopher Landry, Maˇsa Prodanovi´c, Kitty Milliken, “MudrockNet: Semantic segmentation of mudrock SEM images through deep learning”, Computers & Geosciences, 158 (2022) 104952
[58] Roman Juránek, Jakub Výravský, Martin Kolář, David Motl, Pavel Zemčík, “Graph-based deep learning segmentation of EDS spectral images for automated mineral phase analysis”, Computers & Geosciences, 165 (2022) 105109
[59] Yongji Wang, Qingwen Qi, Ying Liu, Lili Jiang, Jun Wang, “Unsupervised segmentation parameter selection using the local spatial statistics for remote sensing image segmentation”, Int J Appl Earth Obs Geoinformation, 81 (2019) 98-109
[60] Sayyed Hamed Alizadeh Moghaddam, Mehdi Mokhtarzade, Behnam Asghari Beirami, “A feature extraction method based on spectral segmentation and integration of hyperspectral images”, Int J Appl Earth Obs Geoinformation, 89 (2020) 102097
[61] Esmail Hosseini-Fard, Amin Roshandel-Kahoo, Mehrdad Soleimani-Monfared, Keyvan Khayer, Ali Reza Ahmadi-Fard, “Automatic seismic image segmentation by introducing a novel strategy in histogram of oriented gradients”, Journal of Petroleum Science and Engineering, 209 (2022) 109971
[62] Michele Volpia, Devis Tuia, “Deep multi-task learning for a geographically-regularized semantic segmentation of aerial images”, ISPRS Journal of Photogrammetry and Remote Sensing, 144 (2018) 48-60
[63] Yu Shen, Jianyu Chen, Liang Xiao, Delu Pan, “Optimizing multiscale segmentation with local spectral heterogeneity measure for high resolution remote sensing images”, ISPRS Journal of Photogrammetry and Remote Sensing, 157 (2019) 13-25
[64] Xueliang Zhang, Pengfeng Xiao, Xuezhi Feng, “Object-specific optimization of hierarchical multiscale segmentations for high-spatial resolution remote sensing images”, ISPRS Journal of Photogrammetry and Remote Sensing, 159 (2020) 308-321
[65] Phuong D. Dao, Kiran Mantripragada, Yuhong He, Faisal Z. Qureshi, “Improving hyperspectral image segmentation by applying inverse noise weighting and outlier removal for optimal scale selection”, ISPRS Journal of Photogrammetry and Remote Sensing, 171 (2021) 348-366
[66] Yunyun Yang, Dongcai Tian, Boying Wu, “A fast and reliable noise-resistant medical image segmentation and bias field correction model”, Magnetic Resonance Imaging, 54 (2018) 15-31
[67] Xin Zheng, Yong Wang, Guoyou Wang, Jianguo Liu, “Fast and robust segmentation of white blood cell images by self-supervised learning”, Micron, 107 (2018) 55-71
[68] Shuchao Pang, Anan Du, Zhenmei Yu, Mehmet A. Orgun, “2D medical image segmentation via learning multi-scale contextual dependencies”, Methods, 202 (2022) 40–53
[69] Bugra Özdemir, Ralf Reski, “Automated and semi-automated enhancement, segmentation and tracing of cytoskeletal networks in microscopic images: A review”, Computational and Structural Biotechnology Journal, 19 (2021) 2106–2120
[70] Gideon Okpoti Tetteh, Alexander Gocht, Christopher Conrad, “Optimal parameters for delineating agricultural parcels from satellite images based on supervised Bayesian optimization”, Computers and Electronics in Agriculture, 178 (2020) 105696

[71] Alwaseela Abdalla, Haiyan Cen, Ahmed El-manawy, Yong He, “Infield oilseed rape images segmentation via improved unsupervised learning models combined with supreme color features”, Computers and Electronics in Agriculture, 162 (2019) 1057-1068
[72] Ehsan Raei, Ata Akbari Asanjan, Mohammad Reza Nikoo, Mojtaba Sadegh, Shokoufeh Pourshahabi, Jan Franklin Adamowski, “A deep learning image segmentation model for agricultural irrigation system classification”, Computers and Electronics in Agriculture, 198 (2022) 106977
[73] Jidong Lv, Huanmin Ni, Qi Wang, Biao Yang, Liming Xu, “A segmentation method of red apple image”, Scientia Horticulturae, 256 (2019) 108615
[74] Dehua Gao, Lang Qiao, Di Song, Minzan Li, Hong Sun, Lulu An, Ruomei Zhao, Weijie Tang, Jinbo Qiao, “In-field chlorophyll estimation based on hyperspectral images segmentation and pixel-wise spectra clustering of wheat canopy”, biosystems engineering, 217 (2022) 41-55
[75] Idir Filali, Brahim Achour, Malika Belkadi, Mustapha Lalam, “Graph ranking based butterfly segmentation in ecological images”, Ecological Informatics, 68 (2022) 101553
[76] Vijai Singh, “Sunflower leaf diseases detection using image segmentation based on particle swarm optimization”, Artificial Intelligence in Agriculture, 3 (2019) 62–68
[77] Ri Jin, Guirong Weng, “A robust active contour model driven by pre-fitting bias correction and optimized fuzzy c-means algorithm for fast image segmentation “, Neurocomputing, 359 (2019) 408–419
[78] Xue Wang, Zhanshan Li, Yongping Huang, Yingying Jiao, “Multimodal medical image segmentation using multi-scale contextaware network”, Neurocomputing, 486 (2022) 135–146
[79] Xu Chen, Yue Zhao, Chuancai Liu, “Medical image segmentation using scalable functional variational Bayesian neural networks with Gaussian processes”, Neurocomputing, 500 (2022) 58–72
[80] Hai-yan Yu, Xiao-bin Zhi, Jiu-lun Fan, “Image segmentation based on weak fuzzy partition entropy”, Neurocomputing, 168 (2015) 994–1010
[81] Maria Baldeon-Calisto, Susana K. Lai-Yuen, “AdaResU-Net: Multiobjective adaptive convolutional neural network for medical image segmentation”, Neurocomputing 392 (2020) 325–340
[82] Le Zou, Liang-Tu Song, Thomas Weise, Xiao-Feng Wang, Qian-Jing Huang, Rui Deng, Zhi-Ze Wu, “A survey on regional level set image segmentation models based on the energy functional similarity measure”, Neurocomputing, 452 (2021) 606–622
[83] Huaqi Zhang, Jie Liu, Zekuan Yu, Pengyu Wang, “MASG-GAN: A multi-view attention superpixel-guided generative adversarial network for efficient and simultaneous histopathology image segmentation and classification”, Neurocomputing, 463 (2021) 275–291
[84] Xiangxiang Cui, Shi Chang, Chen Li, Bin Kong, Lihua Tian, Hongqiang Wang, Peng Huang, Meng Yang, Yenan Wu, Zhongyu Li, “DEAttack: A differential evolution-based attack method for the robustness evaluation of medical image segmentation”, Neurocomputing, 465 (2021) 38–52
[85] Qikui Zhu, Yanqing Wang, Bo Du, Pingkun Yan, “OASIS: One-pass aligned atlas set for medical image segmentation”, Neurocomputing, 470 (2022) 130–138
[86] Qiang Wang, Yingkui Du, Huijie Fan, Chi Ma, “Towards collaborative appearance and semantic adaptation for medical image segmentation”, Neurocomputing, 491 (2022) 633–643
[87] Imene Mecheter, Maysam Abbod, Habib Zaidi, Abbes Amira, “Brain MR images segmentation using 3D CNN with features recalibration mechanism for segmented CT generation”, Neurocomputing, 491 (2022) 232–243
[88] Donghai Zhai, Bijie Hu, Xun Gong, Haipeng Zou, Jun Luo, “ASS-GAN: Asymmetric semi-supervised GAN for breast ultrasound image segmentation”, Neurocomputing, 493 (2022) 204–216
[89] Zhenghua Xu, Shijie Liu, Di Yuan, Lei Wang, Junyang Chen, Thomas Lukasiewicz, Zhigang Fu, Rui Zhang, “x-net: Dual supervised medical image segmentation with multi-dimensional self-attention and diversely-connected multi-scale convolution”, Neurocomputing, 500 (2022) 177–190
[90] Minh Hieu Phan, Son Lam Phung, Khoa Luu, Abdesselam Bouzerdoum, “Efficient Hyperspectral Image Segmentation for Biosecurity Scanning Using Knowledge Distillation from Multi-head Teacher”, Neurocomputing, 695 (2022) 096
[91] E. Mahmoudzadeh, M.A. Montazeri, M. Zekri, S. Sadri, “Extended hidden Markov model for optimized segmentation of breast thermography images”, Infrared Physics & Technology, 72 (2015) 19–28
[92] Maryam Habba, Mustapha Ameur, Younes Jabrane, “A novel Gini index-based evaluation criterion for image segmentation”, Optik, 168 (2018) 446–457

[93] Huizhu Pan, Wanquan Liu, Ling Li, Guanglu Zhou, "A novel level set approach for image segmentation with landmark constraints", Optik – International Journal for light and electron optics, 182 (2019) 257-268
[94] Hong'an Li, Jiangwen Fan, Qiaozhi Hua, Xinpeng Li, Zheng Wen, Meng Yang, "Biomedical sensor image segmentation algorithm based on improved fully convolutional network", Measurement, 197 (2022) 111307
[95] Kunwar Muhammed Saaim, Saima Khan Afridi, Maryam Nisar, Saiful Islam, "In search of best automated model: Explaining nanoparticle TEM image segmentation", Ultramicroscopy, 233 (2022) 113437
[96] G.A. Wachs-Lopes, R.M. Santos, N.T. Saito, P.S. Rodrigues, "Recent Nature-Inspired algorithms for medical image segmentation based on tsallis statistics", Commun Nonlinear Sci Numer Simulat, 88 (2020) 105256
[97] Ashish Kumar Bhandari, Kusuma Rahul, "A context sensitive Masi entropy for multilevel image segmentation using moth swarm algorithm", Infrared Physics & Technology, 98 (2019) 132-154
[98] C. Shanmugama, E. Chandira Sekaran, "IRT image segmentation and enhancement using FCM-MALO approach", Infrared Physics & Technology, 97 (2019) 187-196
[99] Qingju Tang, Shuaishuai Gao, Yongjie Liu, Fengyun Yu, "Infrared image segmentation algorithm for defect detection based on FODPSO", Infrared Physics & Technology, 102 (2019) 103051
[100] Guangpu Shao, Tianjiang Wang, "Robust infrared spectral deconvolution for image segmentation with spatial information regularization", Infrared Physics & Technology, 102 (2019) 103011
[101] Shaohui Chen, Xiaogang Xu, Ningyu Yang, Xianghua Chen, Feng Du, Shuyong Ding, Wei Gao, "R-Net: A novel fully convolutional network–based infrared image segmentation method for intelligent human behavior analysis", Infrared Physics & Technology 123 (2022) 104164
[102] Shasha Ren, Qiong Liu, Xiaodong Zhang, "MPSA: A multi-level pixel spatial attention network for thermal image segmentation based on Deeplabv3+ architecture", Infrared Physics & Technology, 123 (2022) 104193
[103] Huaian Chen, Yi Jin, Guiqiang Li, Biao Chu, "Automated cement fragment image segmentation and distribution estimation via a holistically-nested convolutional network and morphological analysis", Powder Technology, 339 (2018) 306-313
[104] Yu Songa, Zilong Huangb, Chuanyue Shena, Humphrey Shic, David A. Langed, "Deep learning-based automated image segmentation for concrete petrographic analysis", Cement and Concrete Research, 135 (2020) 106118
[105] Yang Liu, Zelin Zhang, Xiang Liu, Lei Wang, Xuhui Xia, "Efficient image segmentation based on deep learning for mineral image classification" Advanced Powder Technology, 32 (2021) 3885-3903
[106] Narges Kheradmandi, Vida Mehranfar, "A critical review and comparative study on image segmentation-based techniques for pavement crack detection", Construction and Building Materials, 321 (2022) 126162
[107] V. Punithavathi, D. Devakumari, "A new proposal for the segmentation of breast lesion in mammogram images using optimized kernel fuzzy clustering algorithm", Materials Today: Proceedings, xxx (xxxx) xxx
[108] Swedika Sharma, "Assessment on image segmentation development techniques by thresholding strategies", Materials Today: Proceedings, 45 (2021) 3336-3342
[109] K. Deeparani, P. Sudhakar, "Efficient image segmentation and implementation of K-means clustering", Materials Today: Proceedings, 45 (2021) 8076-8079
[110] M. Ramaraj, D. Sabareeswaran, G. Angeline Prasanna, "Modified color pixel-based image segmentation using fbmc algorithms used with real time image database", Materials Today: Proceedings, xxx (xxxx) xxx
[111] R Srikanth, Kalagadda Bikshalu, "Efficient Image Segmentation of Natural Images with Noise using Energy Curved Based on Electromagnetism Optimization Algorithm", Materials Today: Proceedings, 46 (2021) 4082-4090
[112] Priyadarsan Parida, Nilamani Bhoi, "Fuzzy clustering-based transition region extraction for image segmentation", Engineering Science and Technology, an International Journal, 21 (2018) 547-563
[113] Jaya Brindha G., Gopi E.S., "A hierarchical approach for automatic segmentation of leaf images with similar background using kernel smoothing based Gaussian process regression", Ecological Informatics, 63 (2021) 101323
[114] Rui Zhang, Guangyun Li, Thomas Wunderlich, Li Wang, "A survey on deep learning-based precise boundary recovery of semantic segmentation for images and point clouds", 102 (2021) 102411
[115] Yanheng Wang, Lianru Gao, Danfeng Hong, Jianjun Sha, Lian Liu, Bing Zhang, Xianhui Rong, Yonggang Zhang, "Mask DeepLab: End-to-end image segmentation for change detection in high-resolution

remote sensing images", International Journal of Applied Earth Observations and Geoinformation, 104 (2021) 102582

[116] Seyed Mohammad Hassan Erfani, Zhenyao Wu, Xinyi Wu, Song Wang, Erfan Goharian, "ATLANTIS: A benchmark for semantic segmentation of waterbody images", Environmental Modelling and Software, 149 (2022) 105333

[117] Chengqian Zhang, Xiaodong Chen, Shunying Ji, "Semantic image segmentation for sea ice parameters recognition using deep convolutional neural networks", International Journal of Applied Earth Observations and Geoinformation, 112 (2022) 102885

[118] Junting Song, Wenbin Jiao, Katie Lankowicz, Zhonghua Cai, Hongsheng Bi, "A two-stage adaptive thresholding segmentation for noisy low-contrast images", Ecological Informatics, 69 (2022) 101632

[119] Tao Lei, Asoke K. Nandi, "Image Segmentation Principles, Techniques, and Applications", 1 (2023) 5-9;13;14, WILEY