COMPREHENSIVE REVIEW ON IMAGE SEGMENTATION APPLICATIONS

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ABSTRACT— *Image segmentation is a commonly used procedure in digital image processing and exploration to partition an image into several parts or regions, often based on the features of the pixels in the image. In computer vision, segmentation refers to the process of subdividing a digital image into multiple segments. More precisely, image segmentation is the method of allocating a label to each pixel in an image such that pixels with the same label share certain pictorial characteristics. Image segmentation techniques have gained increasing and essential importance in a wide range of applications as computer technology has advanced. This study provides a detailed review of image segmentation applications in different domains.*

Keywords—Image segmentation, CBIR, Object detection

1. INTRODUCTION

One of the basic skills of Human Pictorial System is the capability of grouping the image into a set of areas, which contains pixels with some common physical appearance or common physical characteristics. This task is usually stated as segmenting image. The common features used as foundation for the subdivision can be a simple pixel property such as gray level or color shade. However, an image can also be segmented according to a more difficult non-local stuff such as texture [1].

Image segmentation is one of the most significant steps foremost to the analysis of processed image data. Its main goal is to split an image into parts that have a strong correlation with matters or parts of the real world enclosed in image. We can think, Image segmentation as the first look that we made at the world when we were newborn. In other words, it is the technique to look into image without higher knowledge about the objects in the scene. Hence, it is not possible to identify the different objects simply because it is the first time that we see them. Segmentation applications range from industrial control to medicine, robot navigation, geophysical exploration, and military applications [1, 2].

Image segmentation is observed as most important step after image preprocessing in most of the image retrieval, object recognition, Biometrics, medical image analysis, food grain quality assessment algorithms. Segmenting image is a significant image procedure well known by its efficacy and difficulty. To abstract the valuable material from images or collections of images, an unavoidable phase is to separate the matters from the background. Subdivision is just the precise practice and system vital for this task. Segmenting Image is often termed as the practice that segments an image into its essential parts and mines those portions of importance (objects). It is one of the most complex tasks in automatic image investigation, which is at the middle layer of image engineering. Image engineering (which is composed of three layers from bottom to top: (1) image processing, (2) image analysis, and (3) image understanding) is a new discipline and a general framework for all image techniques [2].

Segmentation of nontrivial images is one of the most difficult tasks in image processing. During the past years many segmentation techniques have been developed and different classification schemes for these techniques have been proposed. However, any individual image segmentation technique is not likely to achieve reliable results under all circumstances. This is especially true if the images were obtained under different conditions and have different content [1].

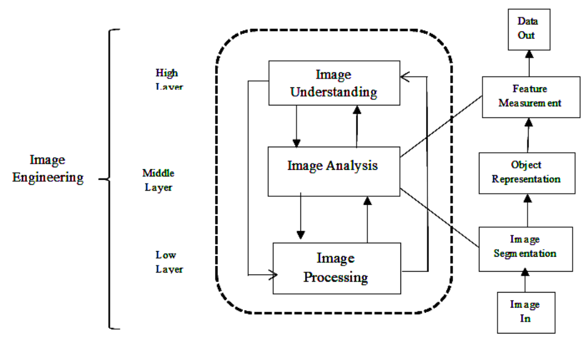

Figure 1. Image Engineering

Image segmentation is a central footstep in computer vision. Machines need to distribute visual data into regions for segment-specific processing to take place. Image segmentation thus finds its application in various fields like Automation, Robotics, Health Imaging, Autonomous Vehicles, and Intelligent Video Analytics [5, 6],. Apart from these applications, Image segmentation is also employed by geographical information systems on satellite imagery for segmenting out roads, buildings, and trees. Following section presents most common real-life use cases of image segmentation applications in various fields

2. ROBOTIC VISION

Image segmentation helps the machine detect and navigate by guiding entities along their path, allowing them to successfully change paths and recognize the context of their location. Aside from motion, image segmentation benefits the machine by isolating the object it is processing and allowing it to interact with the real thing using only the visualization as a reference. This means the machine can be used almost anywhere without major restrictions [7].

Object recognition from images is a universal task that involves many techniques such as image segmentation, image processing, machine learning, linear algebra, statistics, etc. Much research has already been done in the field of image segmentation. A high-level division of available techniques is discontinuity detection and similarity detection [2]. The first category uses edge detection to detect region boundaries [2]. The second category consists of the following techniques: thresholding, clustering, motion segmentation and color segmentation [8, 2].

Research on visual perception indicates that human vision is based on seeing change. In the field of robot vision, change vision is also essential because environments are primarily dynamic: robots operate in a dynamically changing world and may have the ability to move [34. 35].

3. SMART CITIES

Smart cities often have CCTV cameras to monitor pedestrians, traffic and crime in real time. This tracking can be easily automated using image segmentation. With monitoring based on artificial intelligence, crimes can be learned more quickly, emergency services respond immediately to traffic accidents, and speeding cars can be easily caught and punished [7].

The use of image segmentation and AI-based tracking can thus improve people's lifestyles.

- Pedestrian recognition
- Transportation analysis
- Number Plate detection
- Video Scrutiny

4. SELF DRIVING CARS

Self-driving cars are one of the largest applications of image segmentation and rely heavily on it for route and trip planning. Semantics and instance segmentation enable these vehicles to identify road patterns and other vehicles for a hassle-free and smooth ride [7, 9].

- Drivable roads semantic segmentation
- Car and pedestrian finding
- In-vehicle object discovery
- Pothole finding

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5. MEDICAL IMAGE SEGMENTATION

From 3D image data such as magnetic resonance imaging (MRI) and computed tomography (CT) images, specific areas of interest are identified as part of the segmented image for medical images. The overall purpose of segmenting this data is to identify interesting bodily areas for intensive study. Examples include automated settling of CAD-designed transplants in patients and simulation. The tedious task of segmenting medical images has now been made easier by current advances in artificial intelligence (AI) and software technology. One of the important benefits of segmenting medical images is that it allows for a more detailed investigation of anatomical data by considering only essential areas. For some processes, such as implant strategy, it is necessary to focus and separate out certain parts for detailed study, for example in the hip or knee. Additionally, segmentation allows the advantage of eliminating any undesirable particulars from a scan, such as air, as well as permitting different matters such as bone and lenient tissues to be separated. When used with different image options, investigators and medical practitioners can produce a series of segmented masks that are set for additional analysis [12, 13, 14, 15].

One of the most important steps in planning during radiotherapy preparation is accurate slicing of medical pictures. The most commonly used radiographic techniques for diagnosis, clinical research, and treatment planning are computed tomography (CT) and magnetic resonance imaging (MR). When working with CT, MRI, and other types of scans, segmentation generally works by taking information from the background image data and using it to generate a mask. Depending on the task, users may work on their scans in 2D or 3D. There are many different tools and algorithms available in segmentation software, for example wholly manual choices to paint on the data, or semi-automated procedures such as thresholding and region growing. Applications are also available for cardiovascular image segmentation, with particular options for working with different heart cases [12, 13, 14, 15].

With increasing use of computer-aided diagnosis (CAD) helps in automating the process so that large number of cases can be handled with the same accuracy. It also supports faster communication, wherein patient care can be extended to remote areas using information technology [12. 13, 14, 15].

The segmentation approaches for medical pictures differ depending on the necessities, algorithm, and kind of bodily component being inspected. There isn't a solo system that may be engaged to fragment any given medical picture. Each diagnostic device has unique restrictions.

A. Visualization of Brain Image using Segmentation

Brain segmentation provides a way to see distinct brain regions. Statistical measurement and shape evaluations are often used to describe people in both healthy and sick conditions. The gold standard in segmentation is regarded to be manual segmentation by clinical specialists. However, the procedure takes a long time and is not useful for labeling huge amounts of data. Large clinical data sets could be automatically labeled using trained segmentation techniques like convolutional neural networks [12].

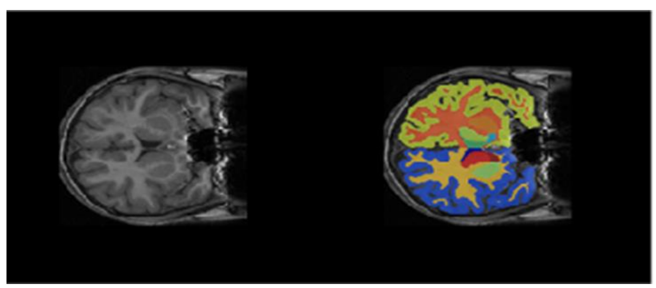

Figure 2. Brain MRI Segmentation Example (Source Mathsworks)

B. MR Liver Image Segmentation

Given the heterogeneous appearance of liver metastases on MR images, the automated identification and classification of liver metastases remains a difficult job. Radiologists may be able to discover metastases more quickly and accurately if automatic hepatic metastases detection is used. Hepatic MR Pictures can be segmented using a variety of methods [12].

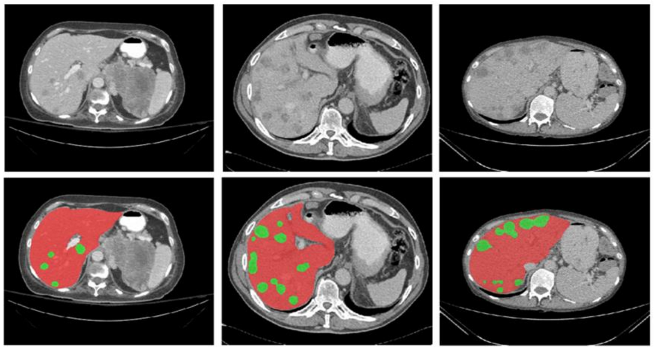

Figure 3: Examples of liver and tumor segmentation [11]

6. PATTERN RECOGNITION

Pattern recognition is considered as allocation of a physical entity or event to one of different pre-defined class. Pattern recognition can mine particular patterns from imageries or videos then used them for face, iris recognition, associating the novel patterns with lots of other images deposited in the database. Pattern recognition offers machines human recognition brainpower, which image processing applications require. Applications of pattern recognition are optical character recognition, biometrics systems such as face recognition, iris recognition, finger prints recognition, speech recognition, medical diagnosis systems such as X-Ray, MRI image analysis etc., military and remote sensing applications such as image segmentation, analysis of aerial photographs etc. Image segmentation is crucial and challenging task due to different lighting and environment conditions in face recognition, iris recognition and satellite image analysis applications.

A. Face Recognition

In Biometric systems such as face image separation from image under different background conditions refers to the procedure of isolating the facial image into numerous specific and distinctive parts, and recognizing entities of interest in these districts [16, 20]. In modern years, facial image segmentation tools have been commonly employed in face image analysis and understanding. Face image segmentation is a central phase concerning facial image processing and face image analysis. Present facial image segmentation methods can be partitioned into the three categories: knowledge-based, model matching, and skin color-based [16, 17, 18, 19, 20].

Perfect and firm segmentation of the face is important to increase the quickness and accurateness of recognition. Conversely, by reason of the impacts of head position, obstruction, image positioning, lighting conditions and face appearance, face image identification and separation is naturally hard task. Initial investigation of images having faces mainly concentrated on the tuning model, the adjusting image, and the deformation method. Images are typically acquired in simple backgrounds and other unchanged conditions; thus, their image acquisition arrangements are quite fixed. Nowadays, face image segmentation have become an investigation topic for researchers. Many methods have been developed, comprising approaches that sense movement, skin color, and other information. Remarkable progress has been done in the investigation of methods that can determine facial features with precise positions [16, 17, 18, 19, 20].

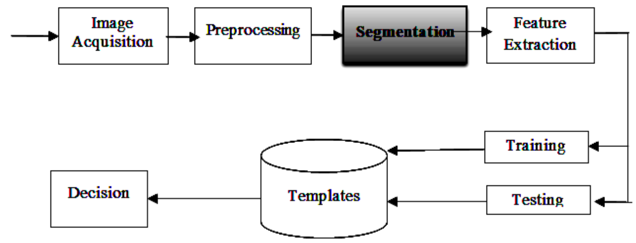

Figure 3: Face Recognition System

B. IRIS Recognition

The iris is observable from exterior and is one of the sheltered body part in humanoid body which is situated after the cornea [21]. Patterns in Iris are observable patterns are matchless to all individuals. There is no individual in this world having the same iris structure not even the identical twins. Person verification system such as Iris recognition is the utmost consistent and precise person identification system. Iris recognition system acquires an image of a human eye; the iris in the image is separated and standardized for mining its feature. The perfection and accuracy of iris recognition systems relies on the method used for segmentation of iris from the eye image. Segmentation is one of the very important steps in iris recognition procedure because image parts that are mistakenly segmented out as iris regions will result in incorrect biometric templates leading to the very poor recognition system. Various methods are available for segmenting iris from eye image. Typical iris identification/ recognition procedure consists of following steps [21, 22, 23, 24, 25]:

- Eye Image acquisition
- Preprocessing
- Iris Segmentation
- Normalization
- Feature Extraction
- Feature Selection / Template Generation
- Matching
- Decision

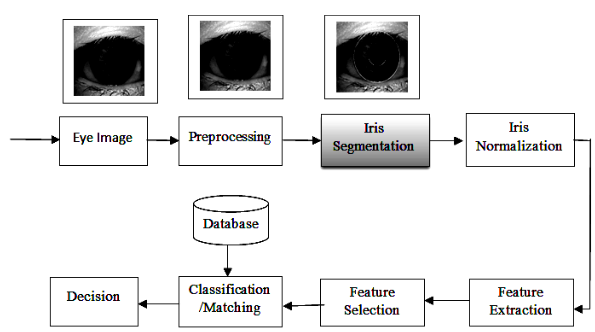

Figure 4. Typical Iris Recognition System

7. REMOTE SENSING

The primary exploration challenge in remote sensing at this time is unquestionably extracting information from image data. Numerous crucial end-users uses, such as terrestrial cover classification, town planning, or change detection [26, 27, 28], are what spur on the intense and relentless interest in this area of study. These sophisticated applications make use of basic data processing techniques like segmentation, synthesis, and image improvement [26, 29, 30, 31]

Particularly for remote sensing applications, segmentation has always been of utmost importance, and numerous potent methods have been put forth over time [26], frequently yielding excellent outcomes in difficult real-world situations. The investigation of remote sensing data is increasingly focusing on object-based methods for image analysis as EARTH observation data with higher spatial and spectral resolution become accessible [33]. Making use of regions or segments of an image as basic units in object-based analysis as opposed to traditional pixel-based analysis has a number of advantages, including reduced spectral variability and more spatial and contextual information, including shape and topological relationships [33]. Image segmentation, which divides an image into non - overlapped regions in order to ensure every region is as homogeneous and neighboring ones as different as feasible, is a crucial step in object-based analysis. Building elements for object-based analysis have been presented by segmentation [26-31]

The major type of image that remote sensing radiometers obtain is multispectral (MS), and MS images offer significantly improved ground object characterization capabilities. High-resolution images, meanwhile, have ample texture information, which has been proved to enhance segmentation outcomes. As a result, it is likely that both spectral and texture information will be used in remote sensing segmentation techniques [33].

Figure 5. Segmentation Example of aerial image using object based methods [32].

8. EARTH OBSERVATION

Modern Earth observation sensors are accumulating massive amounts of digital satellite and aerial images every day [36]. The true challenge is to rapidly analyses the raw images, obtain correct, meaningful data, and use it to make choices and resolve problems in the real world. There are currently a plenty of unlabeled images that represent various things on the Earth's surface. Such pictures can be studied using machines to evaluate various natural factors containing municipal monitoring [37], disaster management, [39], agriculture monitoring [40], and natural resources management [41].

9. AGRICULTURE PRODUCT QUALITY ASSESSMENT

Farming is the firstborn and most common manufacturing in India. In farming science, computerization increases the value, financial growth and production of the country. The decisive visual characteristic of fruits and vegetables is look that impacts their marketplace, the purchaser’s preference and choice. It is necessary to advance the agricultural sector in India in order to satisfy the needs of the country's steadily growing populace. Due to automation, high quality and safety standards must be met, and this can be done with farm goods by correctly, rapidly, and cheaply determining their quality [42, 45].

Traditionally quality of food product is defined from its physical and chemical properties by human sensory panel which is time consuming, may be varying results and costly. Although, the sorting and grading can be done by human but it is inconsistent, time consuming, variable, subjective, onerous, expensive and easily influenced by surrounding. Image processing techniques have been applied increasingly for food quality evaluation in recent years. Thresholding-based, k-means image [43] and other different segmentation methods can be used to determine size, shape, color, and texture features of agriculture products.

10. AGRICULTURE CROP DISEASE IDENTIFICATION

In farming, crop management calls for close monitoring, particularly for the prevention of diseases that can significantly affect production. Disease detection might hold the key to avoiding losses in the farming sector. For the purpose of predicting agricultural and plant diseases in agriculture, techniques like image preprocessing and segmentation can be united with soft computing methods like AI and machine learning [46].

11. IMAGE PROCESSING APPLICATIONS

Some of the image classification and retrieval applications of image segmentation are CBIR System, Object detection and Tracking

CBIR is an image retrieval system that retrieves similar type of images from database of images. Generating a novel set of descriptors for feature matching is challenging task in IR Systems. Image Segmentation algorithms are used for generating feature descriptors based on shape, texture and object boundaries. It is good to integrate image segmentation into IR systems to improve retrieval accuracy of IR Systems [47].

Object detection outlines bounding box around the objects in image. A further advancement of object detection is image segmentation, which indicates the presence of an object utilizing pixel-wise masks generated for each entity in the picture. Instead of making bounding boxes around every object as in bounding box generation, segmentation allows us to identify the shape of each object in the picture by determining the pixels that constitute that object, making it a more granular method [49].

Object Tracking is a basic operation in video applications requiring tracking of objects of interest in video as to form relation between objects in video frames. It finds applications in spontaneous surveillance, truck navigation, video labeling, and movement recognition. For numerous tasks, object tracking in video is done online. Combined with object tracking segmentation is also needed to find position of object of interest in frame [50].

TABLE I. SUMMARY OF IMAGE SEGMENTAITON APPLICATIONS

No.	Real World Uses	Purpose
1	Image Processing	1. CBIR Systems [47] 2. Object Detection [49] 3. Object Tracking [50] 4. Video Processing [6] 5. Image Sharpening [6]
2	Medical Applications	1. Computer Aided Diagnosis [12] 2. MRI. CT, X Ray Image Analysis 3. Brain, Liver Image Segmentation 4. Tissue Volume Measurement [12] 5. Planning Radio Therapy [12]
3	Remote Sensing	1. Aerial Image Segmentation [26] 2. Object Based Image satellite Image Segmentation [26] 3. Semantic Segmentation of satellite images [27] 4. Landscape change/cover detection 5. Urban Planning [27]
4	Earth Observation	1. Municipal monitoring [37] 2. Calamity management, [39] 3. Agriculture monitoring [40], and 4. Natural resources management [41]. 5. Traffic Control Systems\ 6. Flood Monitoring
5	Agriculture Imaging	1. Crop Disease Identification [42] 2. Grading of Vegetables, Food Grains, Fruits etc [43, 46, 45]
6	Industrial Automation Applications	1. Robot Vision [7] 2. Drones [7, 9] 3. Self-Driving Cars [7,9] 4. Object Tracking [50]
7	Pattern Recognition	1. Iris Recognition [16, 17] 2. Face Recognition [21. 22]
8	Security	1. Video Surveillance [6] 2. Fingerprint Matching 3. Scene Understanding 4. Online Object Tracking 5. Security Systems
9	Shape Detection	1. Separating and identifying parts in image

12. CONCLUSION

This study provides review of image segmentation applications. Despite four decades of research, Image segmentation and classification is an exciting task in the image processing society because of the variability and complication associated therein. The difficulties of image segmentation turn out to be more uncertain and difficult when it approaches to color image segmentation. A solid computational effort is required to process color images containing natural scenes due to variety of textures and real world objects in image.

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