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Computer-Aided Design on Image Detection: A Chronology Review

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ABSTRACT

In order to conduct research and diagnose diseases, image processing is essential. Medical professionals frequently segment images for pre- and post-surgery decisions, which are necessary for treatment planning. In the medical research field, segmentation is the core subject of several studies. Computer-aided detection (CAD) is utilised to achieve the highest level of classification accuracy and may be used to identify tissues growing abnormally. For the purpose of finding abnormalities, magnetic resonance imaging (MRI) is an effective approach, but it takes time and requires a fair amount of human resources. This approach, however, was problematic for slicing data related to the interior surfaces of cavity structures, for instance, the human skull. As a result, a ray casting algorithm was used to create a software programme. The most significant problem with segmentation techniques for x-ray images is seed point selection. An object's surface structure is described by a three-dimensional (3D) surface structure graph (SSG) that was created during segmentation. Ultrasound image detection is critical today. The model can be further modified using this CAD software so that it can be reproduced on a rapid prototyping device in the STL file format. The suggested deep learning method is exceptionally effective in accurately detecting faults in each layer, according to experimental data.

1. Introduction

Over the past century, there has been an increased study on image detection and processing [1-3]. Magnetic Resonance Imaging (MRI) becomes the effective approach to detecting brain tumors as shown in Figure 1. A summary of radiographic capabilities with a focus on electronic image detection as well as processing employed different techniques, like the method for range image segmentation and it is founded on the blending of edge and region information. The detection of flaws in casting range images is accomplished using an automated visual inspection method. Splines, which were developed by Schoenberg [4] in 1969, provides a sophisticated framework for addressing discretization as well as interpolation issues.

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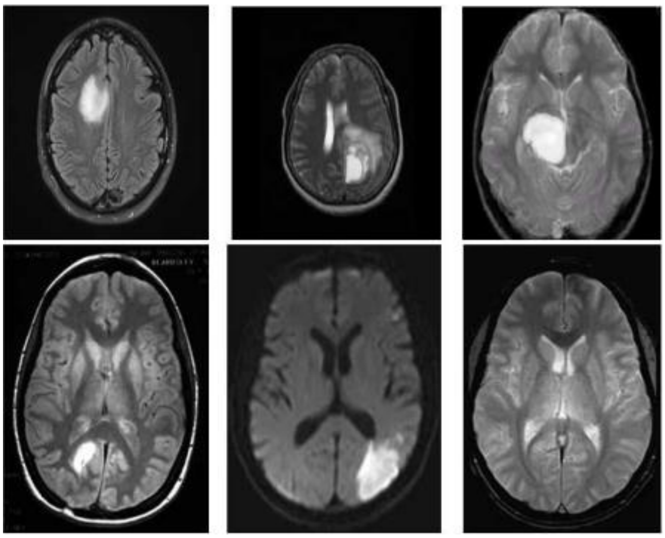

Fig. 1. Brain MR images containing tumor [2]

There are extensively employed in computer-aided design (CAD) as well as computer graphics but have not been utilised in medical imaging applications, primarily due to the "bad press" problem. The benefits of splines have been rediscovered in medical field as a result of several recent research initiatives in signal processing as well as wavelet-related approaches. Splines now provide the greatest cost-performance tradeoff among the various interpolation techniques, according to solid data. Several steps of the system, such as surface classification and inspection, make use of CAD model data. It is becoming less common to combine various technologies to build complex, unsatisfactory electrooptic systems for a range of surveillance, image recognition, detection, as well as other tasks—none of which are performed particularly effectively. Instead of patching collection optics having focal plane detector arrays, a novel imaging sensor technology will use high-speed serial computer technology for image display as well as analysis. The same enabling microfabrication methods, including lithography, CAD, anisotropic etching, as well as grafting, are being used to create new microoptic, microelectronic and micromechanic elements [5,6].

To quickly prototype bone or soft tissue, medical professionals can currently export MRI images to specialised software technologies [7-9]. Smaller medical practices might not have easy access to this specialised software. Thus, a method that would work better with standard computation engineering tools was created. Originally, a technique was used to look at two-dimensional (2D) slice images obtained from the MRI data. Bone boundaries were discovered using a basic edge threshold detection technique. Nevertheless, this approach was problematic for slicing data related to the inner surfaces of cavity features, like the human skull. Additionally, Masum *et al.,* [10] did a three-dimensional (3D) analysis on the 2D ultrasound slices utilising image processing techniques. Using x-ray fluoroscopic images as well as a CAD model of the knee implants, 2D/3D registration approaches have been used in clinical instances to obtain a 3D kinematic analysis of total knee arthroplasty (TKA). Considering that each initial pose setup for an x-ray image required laborious manual procedures in prior work, spurious edges as well as noises from the edge detection concerning the implant silhouette were also manually removed.

There has been a significant issue with clinical applicability. Deep learning of geometric variation for image-guided process monitoring as well as control has not been studied all that much. When used to evaluate the small intestine or the entire digestive tract, wireless capsule endoscopy (WCE) demonstrates its reliability as a great tool to identify ulcer disease from normal WCE images [11,12]. Here, there is no information on the radiopacity concerning the current restorative CAD/computer-aided manufacturing (CAM) materials, despite the fact that the restorative material's radiopacity impacts the teeth's radiographic diagnosis.

This study aims to propose a chronology of the revolution in CAD and image processing in various fields. There has been a large array of improvements achieved in the last few years. The structure of this paper is as follows: The detailed chronology of the linked work's development over several decades is provided in Section 2. Starting from the 2000's until the current year, a significant amount of research is concerned with this area and Section 3 represents the conclusion of this work.

2. Review of the Study

This review's main objective is to learn more about the existing revolution in CAD and image processing in medical practices over a few decades. The chronology starts from the year 2000 until the recent year.

2.1 2000-2019

Microcalcifications (MCCs) in mammograms can be automatically detected and classified using a diagnostic method for mammography screening that was developed by Lee *et al.,* [13] in the early 2000s. It consists of four modules, and one benefit of the system's design is that every module is a different section that can be upgraded separately to enhance the performance of the entire system [13]. In 2010, ten years later, image processing in the medical industry gained popularity. A straightforward method for creating 3D RP physical models is presented by Wang *et al.,* [14] for segmenting CT medical images. Here, the converting process of CT scans to an RP model can be made simpler using stereolithography (STL) triangular meshes as a foundation. Hence, the findings of this study are clinically valid for rebuilding 3D bio-CAD models from CT scans. Breast regions are separated into tiny blocks in Figure 2.

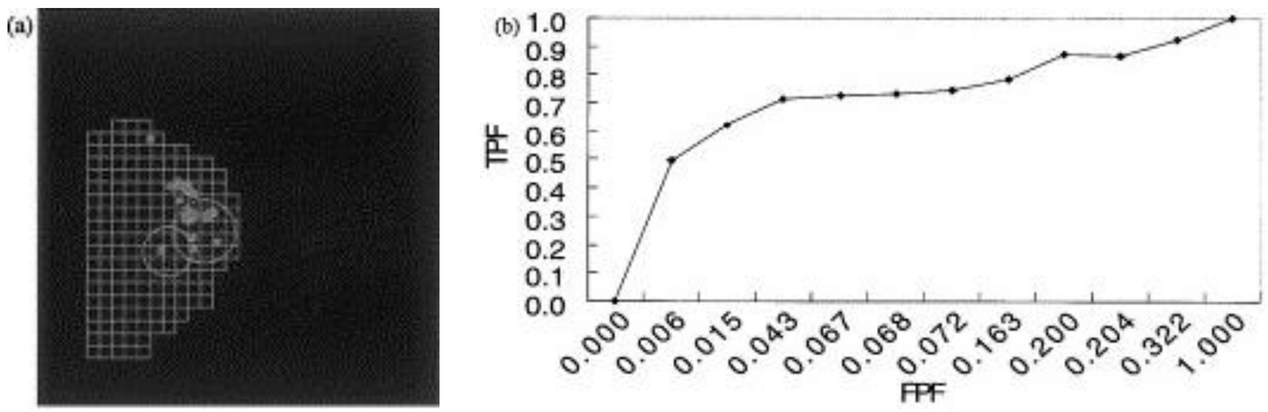

Fig. 2. (a) Breast regions divided into small blocks with size 64×64. (b) ROC curve of TPF versus FPF [14]

In order to determine the events' frequency impacting patient treatment from four radiation oncology process steps: simulation, treatment planning, data entry/transfer, and treatment delivery, as illustrated in Figure 3 by Hunt *et al.,* [15], research from ten years of quality assurance records from January 2001 through December 2010 were retrospectively reviewed in 2012. Although the overall event rate was modest, potential areas for improvement were found, particularly staff overreliance on computer systems, manual data entry and calculations, as well as late-day treatments. Pretreatment events were more likely to occur multiple times before detection and were linked to greater dosimetric impact. Thus, reducing their frequency is especially important. Here, the gantry and the patient couch can collide, which would slow down the commencement of the treatment and lower clinical effectiveness. Relative to the isocentre of the proton therapy room, the machine geometry, as well as the patient, was rebuilt. By examining which patient and couch contour points fall into the spatial polygons created by the proton gantry surfaces, a software program was created utilising a ray casting algorithm to detect collisions. Relying on a ray casting algorithm, the authors created a rapid and clinically viable collision detection tool for proton therapy patients [16].

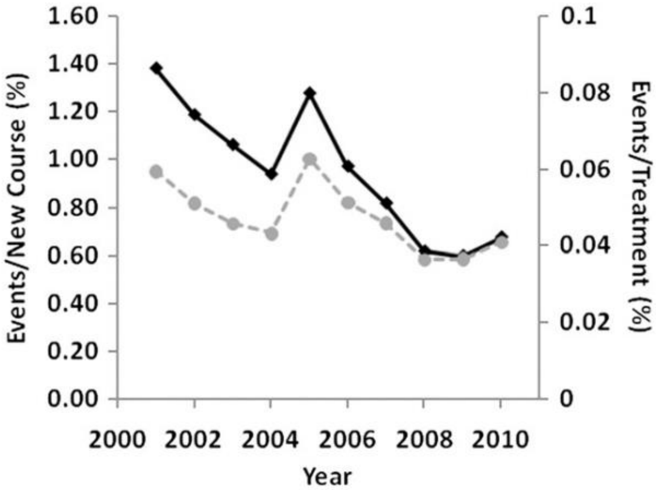

Fig. 3. Events per course of treatment (black diamonds) and treatment delivered (grey circles) for the years 2001-2010 [15]

The suggested algorithm, the MRF-artificial bee colony optimization algorithm, uses the MRI images as a dataset and fuzzy possibility means to get the best result. The major goals of the suggested approach are to increase accuracy while reducing computational complexity. Utilizing region non uniformity, correlation, and computation time, the performance of the suggested algorithm is calculated. The experimental outcomes were contrasted with those of previous methods like simulated annealing and MRF with an upgraded genetic algorithm (GA) [17]. Due to the poor diagnostic accuracy of expert dermatologists, CAD approaches are extremely beneficial for the examination of skin lesions utilising digital dermoscopy. For automatic border detection (ABD), a single strategy is suggested. The normalised smoothing filter (NSF) preprocesses data to lessen background noise. On a set of 100 dermoscopy images having ground truth, the entire ABD system is tested. Results show that the lesion region is accurately segmented using the suggested strategy. Sample datasets and execute software are accessible online and can be downloaded from: http://cs.ntu.edu.pk/research [18].

A new time-domain fault location technique based on the impulse response (image) concerning a power system was demonstrated by Abad *et al.,* [19]. By injecting a series of impulses, the suggested algorithm obtains the power system's electrical image during normal operation. Findings reveal a significant increase in fault distance estimating accuracy when compared to previous algorithms. Fault resistance, high immunity to ground resistivity, as well as fault type and location in the distribution system, are important benefits of the proposed method by Abad *et al.,* [19]. In the medical field, a CAD or diagnosis is essential in detecting breast cancer. On a mammogram image analysis society (MIAS) database, the efficacy of this research is evaluated using the metrics of accuracy, specificity, sensitivity, as well as Mathew's correlation coefficient conducted by Vaidehi *et al.,* [20]. There is a large volume of published studies describing CAD and image processing in 2017, especially in medical fields. Mesleh [21] introduces a CAD system for detecting lung cancer. Neural networks (NNs), multi-layer (ML), as well as independent component analysis (ICA) are employed in lung cancer detection. A total of 460 CT images were used for the validation, training, and testing with respect to the detection algorithm, 350 of which belonged to patients with lung cancer treated in Jordanian hospitals. The system is tailored to detect the cancer presence in real CT images. Levenberg-Marquardt, one of the 11 training algorithms, has the fewest ICA features and the highest classification accuracy of 100%.

Then, a study was done using a novel technique to detect saliency in a 3D multichannel MRI sequence for glioblastoma multiforme (a malignant brain tumor form). The BRATS MICCAI 2015 dataset, which includes 274 glioma cases and includes both low grade as well as high grade GBM, was used to assess the algorithm's performance. From Figure 4, Mitra *et al.,* [23] displays the precision-recall and receiver operator characteristic (ROC) curves by averaging the sets of images from the two data groups, High-grade (HG) as well as Low-grade (LG). The outcomes were contrasted with those obtained using the whole sequence of brain data and the 2D saliency detection algorithm. Moreover, the area under the ROC curve (AUC) was determined to be greater than 0.99 ± 0.01 for all comparisons across a range of tumor kinds, structures, and locations. In an automated cell counting system, Sarrafzadeh *et al.,* [22] searched for the best attributes to distinguish between the five different leukocytes types (lymphocyte, monocyte, eosinophil, neutrophil, as well as basophil) from blood smear microscopic images. For our forthcoming work, they created and constructed a system depending on many characteristics and various classifiers to maximize the accuracy even for each particular cell type. Chondroblastoma is a benign bone tumor that often develops in the cartilage region of bones and spreads to the surrounding tissue. The prevalence of CAD is rising, and this field is among the most actively researched in medicine. SRM algorithm is used for segmentation and this shows better results than the active contour method [24].

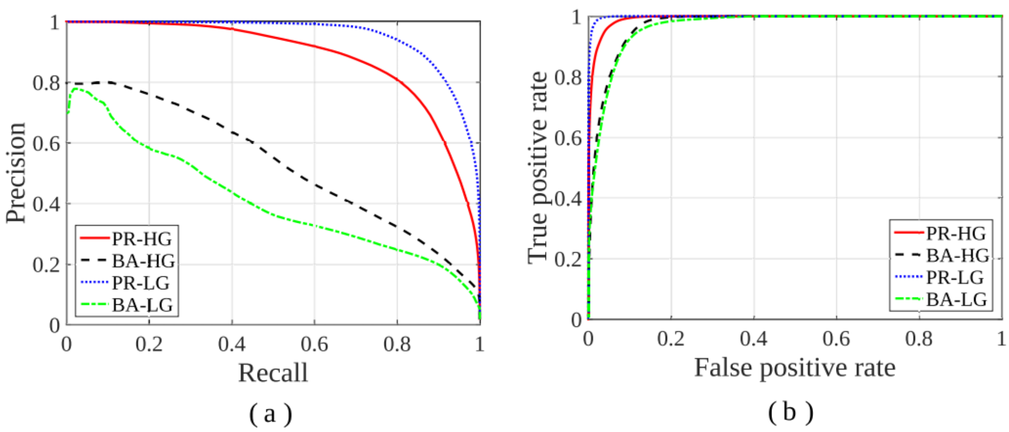

Fig. 4. Comparative study over varying thresholds [0-255] on saliency map for HG and LG tumor images [22]

2.2 2020-2022

A new ultrasonic image feature extraction algorithm that combines edge-based features, as well as morphologic feature information, is suggested in the early 2020s and has a positive impact on the detection of malignant as well as benign breast tumors. According to Liu *et al.,* [25] findings, they demonstrate that edge-based characteristics have the potential to be utilized in breast ultrasound CAD and may effectively define breast tumors in ultrasound images. Here, the primary concern is image segmentation, tumor detection, and tumor area extraction from brain MRI, but these are time-consuming, laborious tasks carried out by clinical experts or radiologists, and the accuracy depends only on their experience. Therefore, it has become crucial to use CAD technology. The two primary imaging modalities used to detect brain tumors are MRI and CT [26]. A study suggested a way to detect and diagnose lung nodules as soon as feasible in order to treat them successfully and lessen the burden on patients and the healthcare system. By relying on the deep learning convolutional neural network (CNN), a lung CT image segmentation algorithm was created by Guo *et al.,* [27]. Yusefi *et al.,* [28] review a synthesis and structural analysis of various magnetic nanoparticles examined for magnetic hyperthermia therapy and controlled drug release in cancer treatment.

The Plasmodium parasite is what causes malaria. Due to inadequate healthcare infrastructure, such expert pathologists might not be accessible in many parts of the world. Consequently, the creation of automated systems is crucial for speedy and accurate malaria detection. It can lower the rate of false negatives and aid in the early diagnosis of diseases so they can be efficiently treated. From microscopic blood images, a CAD is utilised to automatically detect the malarial parasite. The findings demonstrate the proposed algorithm's dependability and demonstrate its significant potential to help pathologists and hematologists detect malaria parasites accurately [29]. For diabetic retinopathy screening systems, CAD is in demand. Microaneurysms are the first signs of non-prolific diabetic retinopathy to be noticed. Wankhede and Khanchandani [30] demonstrate that the suggested technique is efficient in detecting microaneurysms in retinal images to diagnose diabetic retinopathy.

Recently, CAD and image processing have drawn more attention from researchers. There will be more research on this subject in numerous fields in 2022. The detection of physiological alterations taking place within the human body is a challenging task in the field of biomedical engineering. As shown in Figure 5, Joshi *et al.,* [31] proposed work in which they created a CAD system to aid in the early detection of glaucoma as well as the screening and treatment of the disease. Apart from that, the evaluation of the image analysis model's capability for early glaucoma detection and diagnosis, as well as for the assessment of ocular disorders, is the main objective. The proposed CAD system would provide a second opinion as a decision made by human professionals in a controlled setting, assisting the ophthalmologist in the detection of ocular disorders. The first of its kind to be created, the initial module of this method is an ensemble-based deep learning model for diagnosing glaucoma.

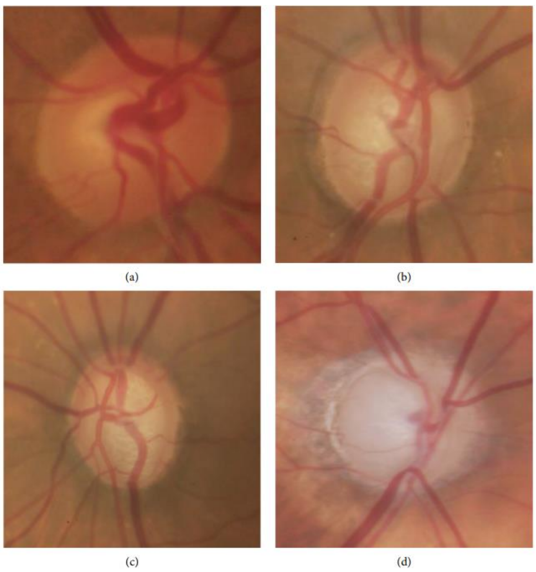

Fig. 5. (a) Normal, (b) early glaucoma, (c) moderate glaucoma, and (d) severe glaucoma [31]

Due to its asymptomatic nature, early-stage lung cancer is difficult to diagnose, especially considering the repetitive radiation exposure and expensive expense of CT. By evaluating and contrasting the chosen profile values in CT images received from patients and control patients upon their diagnosis, the model is first trained to recognise lung cancer [32]. One of the most feared illnesses affecting women globally and responsible for many fatalities is breast cancer. The creation of an automated method for breast masses aids radiologists in making an accurate diagnosis since breast masses early detection increases the life expectancy of women. In order to identify salt-and-pepper, Gaussian, Poisson, and impact noises in mammographic images and to determine the precise mass detection operation following these noise reductions. This research suggests an effective technique for noise reduction in mammographic images. As a result, it provides two methods for precision mass segmentation in mammographic images: the Optimal Social Spider Algorithm (SSA) and Quantum Inverse MFT Filtering for noise reduction operations. When compared to earlier techniques, the hybrid approach known as QIMFT-SSA is judged on parameters including peak Signal-to-Noise Ratio (PSNR) as well as Mean-Squared Error (MSE) in noise reduction and accuracy of detection for mass area recognition proposed by Widiastuti *et al.,* [33].

A thorough collision avoidance framework based on 3D CAD modeling, a graphical user interface (GUI) as an add-on to the radiation treatment planning (RTP) environment, as well as patient-specific plan parameters for intensity-modulated proton therapy (IMPT), was presented by the research in 2022. The delivery mechanism for proton treatment and the position of the robotic couch may both be precisely modeled by the Collision Avoider Software. Clinical beam configurations that are often used and JCT values were examined. The configurations of the gantry and patient positioning systems are more complicated for patients with brain, head, and neck conditions. To verify the geometry of the 3D CAD model, physical measurements were taken [34]. One of the biggest causes of death worldwide is cancer of any kind. Skin cancer is a disorder in which the skin tissues develop malignant cells, such as melanoma, the most fatal and aggressive form of skin cancer. A skin lesion's pre-diagnosis using CAD systems is based on clinical standards or structurally related global patterns. Applying measures for accuracy, sensitivity, and specificity, the suggested model, was evaluated against different models using dermoscopic images from the PH2 database [35]. Brain cancer detection and classification is done utilizing distinct medical imaging modalities CT, MRI. This study focuses on the design of automated Henry Gas Solubility Optimization with a Fusion of Handcrafted and Deep Features (HGSO-FHDF) techniques for brain cancer classification for detecting and classifying different stages of brain tumors as shown in Table 1 [36].

Table 1
Comparative analysis of the HGSO-FHDF model [35]

Methods	Accuracy	Kappa
DNet201 model	94.50	90.24
ResNet50	93.16	90.52
Inc. V3 model	93.04	88.67
M-Net V2 model	93.19	86.89
HGSO-FHDF	96.59	92.33

The use of virtual dental and dental surgical planning, as well as surgical navigation, was promoted by the development of digital technology. The procedure depends on the acquisition and processing of high-quality images. Poor initial quality CT or cone-beam computer tomography (CBCT) images significantly reduce the processing algorithms' performance and have an impact on the reconstructed 3D models' quality. A bone segmentation algorithm for surgical planning is introduced by Dorogi *et al.,* [37], and its advantages for the aforementioned objectives are assessed. Edge detection, mathematical morphology, as well as fundamental image-processing techniques are used in the method. Dental trauma, like luxation injuries, frequently leads to pulp canal obliterations (PCO). The drill's tip needs to be positioned in a true-to-scale virtual image so that it may access the calcified root canal. After the template has been created utilizing CAD and CAM or a 3D printer, guided access cavity preparation can be carried out in a clinical setting. The study by Leontiev *et al.,* [38] describes the static guided endodontic procedure from imaging to clinical use. In the context of recognising dental implants, an approach for creating artificial training samples from triangulated 3D surface models is put forth. In order to automatically detect the connection type associated with a certain dental implant in an actual x-ray image, a fully convolutional network (FCN) is then trained on the artificially produced x-ray images as mention in Kohlakala *et al.,* [39].

3. Conclusions

To give readers new perspectives on the subject of the research, an effort has been made in this area. Figure 6 demonstrates that recent publications have undergone rapid alteration. Consequently, it might be inferred that the CNN-based CT image segmentation algorithm might efficiently detect and diagnose issues as CAD systems for medical practices using ultrasonic modalities gain popularity. The graphical application has offered precise collision detection, and the method can help radiologists find problems early and manage patients effectively, aiding the timely management concerning patients. The algorithm greatly decreases the execution time for surgical planning and segmentation, improving overall operational efficiency. If used in the treatment planning stage, it might increase clinical effectiveness. The detection of patient collisions during photon therapy might potentially be done using this technique. For scanning proton therapy, a highly effective patient-specific collision prevention approach has been put into practice.

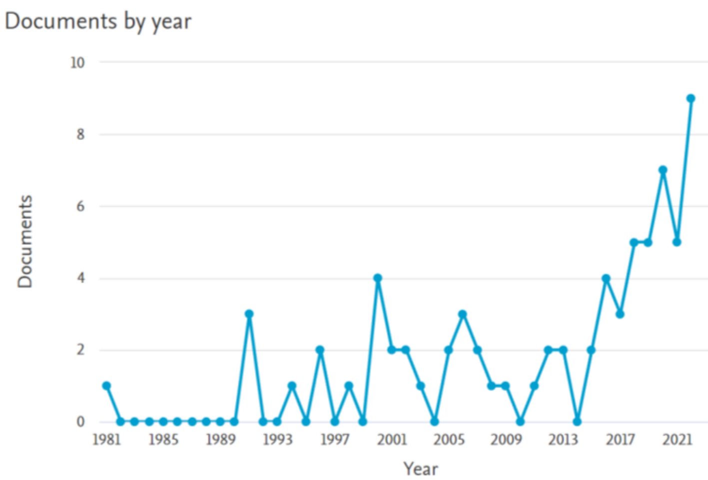

Fig. 6. Articles published by year

Approximal caries detection in CBCT scans may result from artifacts caused by various restorative materials. The approximal caries detection accuracy is improved when the AR option is used with CBCT scans. There are now various software packages available as a result of the gradual rise in clinical interest in the creation of software that enables 3D reconstruction and functional assessment. For instance, the early phases of CAD are analogous to medical image processing, which has emerged as a prominent player in the automatic tumor region detection field. One of the most important uses of medical image processing is saliency detection, which can help medical professionals by making the affected area stand out in the foreground from the rest of the background image.

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