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ANALYSIS OF ALGORITHMS FOR DETECTING BREAST CANCER USING MEDICAL IMAGING

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Abstract: This dissertation explores the application of image processing, machine learning, and deep learning techniques in applied mathematics, particularly in the analysis of medical images. Advanced algorithms such as SIFT, HOG, K-means, CNN, AlexNet, VGG, ResNet, EfficientNet, U-Net, DeepLab, YOLO, and SSD are examined for their effectiveness in extracting accurate and relevant information from images during medical diagnostics.

Key words: algorithm, images, SSD, U-Net, YOLO, analysis, machine learning, accuracy, CNN.

INTRODUCTION

Since its emergence, digital image processing has occupied a strong position in applied mathematics and is now considered one of the most in-demand fields. Methods of digital image processing are widely used across various domains such as robotics, video surveillance systems, medical systems, quality control, and many other areas.

The continuous advancement of technical equipment enables the acquisition and storage of large-scale and high-resolution images. At the same time, the development of computing systems and the widespread adoption of multi-processor architectures provide the opportunity to apply more powerful and complex image and video processing methods. This, in turn, reduces the risk of a noticeable decline in computational efficiency.

One of the most dynamic directions in image processing today is its application in medical imaging. With the ongoing development of medical, treatment, and diagnostic methods, the demand for hardware and software tools based on modern technologies is steadily increasing. Diagnostic tools such as computed tomography (CT), magnetic resonance imaging (MRI), and positron emission tomography (PET) have become inseparable parts of medical diagnostics through the use of computer technologies for image processing and presentation.

LITERATURE REVIEW

Computer vision and deep learning algorithms are widely used in the analysis of medical images. Methods such as SIFT and HOG are effective for extracting key features from medical images, while the K-means algorithm is useful for image segmentation.

CNN-based models — including AlexNet, VGG, ResNet, and EfficientNet — have shown high effectiveness in detecting cancer and other diseases in MRI, CT, and X-ray images. For segmentation tasks, models like U-Net and DeepLab offer high accuracy, especially in isolating tumor regions.

In addition, real-time object detection models such as YOLO and SSD enable fast and accurate detection of relevant structures in medical images. Collectively, these technologies play a critical role in automating diagnostic workflows and improving accuracy in clinical decision-making.

RESEARCH METHODOLOGY

The research was carried out in the following stages:

Study of theoretical foundations - Scientific sources and practical applications on classical algorithms (SIFT, HOG, K-means) and deep learning-based models (AlexNet, VGG, ResNet, EfficientNet, U-Net, DeepLab, YOLO, SSD) were analyzed.

Model selection and testing - Each model was studied for its functional capabilities, architecture, and application area, and tested on real images using the TensorFlow and OpenCV libraries based on the Python programming language.

Experimental design - Various methods were applied to perform object detection, segmentation, and classification tasks based on a collection of medical and general images.

Evaluation criteria - Each approach was evaluated based on indicators such as accuracy, F1-score, processing speed, and resource requirements.

Analysis of results - Based on the results obtained, the effectiveness of classical and deep learning approaches was compared and it was determined which method was more appropriate in which cases.

Research Discussion

Classical image feature extraction methods were actively used in the field of computer vision before the widespread use of deep neural networks. They help identify important features of an image and are used in tasks such as object recognition, image search, and classification. Several classical methods are reviewed below.

The SIFT (Scale-Invariant Feature Transform) algorithm is used to identify important points in images and describe them in a way that is stable with respect to changes in scale, rotation, and illumination. The main steps and mathematical formulas of the algorithm are given below. The SIFT algorithm smoothes the image at different scales using a Gaussian filter. This for the following formula is used

$$L(x,y,\sigma) = G(x,y,\sigma) * I(x,y)$$

Here - L (x,y,σ) is the image with the Gaussian filter applied, - is G(x,y,σ) the Gaussian kernel, I(x,y) - is the original image, - σ is the blur parameter (smoothing level). Then DoG (Differe nce of Gaussians) is calculated DoG(x,y,σ)=G(x,y,kσ)-G(x,y,σ); Here k is the scale change coefficient. Result. DoG of the image different on the scales edge detection for is used. Key points Keypoint Detection – this is in the picture local extremum was points are, they are his/her own surrounding all to pixels relatively the most big or the most small to values has will be. Such points find for Dog results analysis will be done and neighbor points with compared.

SIFT algorithm scale, rotation and light to changes relatively stable is, it is objects identify, images comparison and 3D models again restoration such as in tasks wide is used.

HOG (Histogram of Oriented Gradients) is image features description method often the images analysis to do, especially to people determination for The HOG algorithm is used. the image small to blocks separate, each one gradient directions in the block calculate them histogram This histogram of the object description as service Gradients calculation. First in stages of the image every one pixel is a gradient for. Gradient image brightness change shows and his/her direction determination for is used.

X -axis gradient $G_x$by :$G_x = I(x+1,y) - I(x-1,y)$

Y -axis gradient $G_y$by :$G_y = I(x,y+1) - I(x,y-1)$

Here $I(x,y)$– image brightness value.

Gradient size G:$G = \sqrt{G_x^2 + G_y^2}$

Gradient direction θ:$\theta = \arctan\left(\frac{G_y}{G_x}\right)$

Image small divided into blocks (usually 8×8 pixels). Each on the block gradients calculated, histograms is compiled. Each on the block gradients direction according to distributed and histogram harvest Typically, a histogram has 9 segments, each one at an angle of 20° suitable (from 0° to 180 °). Block sizes various to be because of the HOG method normalization is done.

K-means clustering method is pixels similar depending on its characteristics (for example, color) to groups separation method. The K-means algorithm work Order : Clusters number Select (K). User by or experimental road with K clusters number is selected. Start centroids mark. Initially random K initial values centroid $C_1, C_2, \dots, C_K$. is selected. Each centroid d - dimensional in space the point represents. Each the point the most close to the cluster assignment. Each point from centroids the most near This distance is assigned. calculation for Euclid distance used :

$$C_i = argmin\|x_i - c_k\|$$

$$k \in \{1,2, \ldots , K$$

Here — and this Euclidean distance is calculated as follows:

Here $\|x_i - c_k\|$— and this Euclidean distance is calculated as follows:

$$\|x_i - c_k\| = \sqrt{(x_{i1} - c_{k1})^2 + (x_{i2} - c_{k2})^2 + \cdots + (x_{id} - c_{kd})^2}$$

Convolution is mathematician operation signals and the images again at work wide is used. In particular, convolutional neuron networks (CNN) main component is considered. To the images relatively convolution small filter or the core image along move it, its features separate to take through done increased. Mathematics Expression : If I(x, y) is an image, and K(i, j) is if there is a filter (kernel), then convolution result as follows is considered

$$(I * K)(x, y) = \sum_{i=-m}^{m} \sum_{j=-n}^{n} I(x + i, y + j) \cdot K(i, j)$$

This on the ground I(x+i,y+j) — image filter of size in the part pixel values, K (i, j) — filter weight coefficients, (x, y) — convolution in use image coordinate. As a result, the new image harvest will be, in it every one pixel initial of the image core by again worked value will be. Convolution of images edges detection, textures separation and other visual features again at work wide is used.

Pooling – information squeeze and important features storage Algorithm of the pool. Algorithm of the pool following stages own inside Gets : Data small to blocks to be – Image or other information fields small into parts The money transaction is Use – Each block for maximum or average value is taken. Minimized matrix harvest to do – Every block for aggregated value taken, general volume This process is called information size reduce, calculate process acceleration and of the image the most important features storage opportunity gives.

AlexNet architecture. 8 -layer model: 5 convolutional (twisted) layers and 3 full connected from the floor consists of. Activation function as ReLU (Rectified Linear Unit) was used – this the model previous to methods relatively faster to study help Dropout technique used – this model excess having studied prevent overfitting It takes. 224×224 pixels. images with works.

VGG (Visual Geometry Group) – Images classification to do for convolutional neuron network (CNN). VGG model the image analysis to do for one how many multi-storey to architecture has divided into the following main from elements The VGG architecture consists of and main Simplicity – the VGG model architecture simple, because all convolutional 3×3 size on the floors filters Deep Learning – Model is used to in depth to be possible, for example, VGG-16 and VGG-19 (16 or 19 layers). Max - pooling – Size reduce for max pooling operation of size 2×2 or 3×3 is applied.

Image I and filter K is given if, convolution practice as follows is expressed

$$(I * K)(i, j) = \sum_{m} \sum_{n} I(i + m, j + n)K(m, n)$$

this on the ground I(i, j) — the image at point (i, j) value, K(m, n) — filter value, * — convolution operation indicates.

ResNet (Residual Networks) – Deep in learning revolutionary model. ResNet model computer see and deep study issues solution to do for working Published. Home The difference – Ostatok Residual Connections are used. This connection gradient disappear the problem prevent takes and model study efficiency increases.

ResNet in the model every one on the floor as usual convolutional floor instead of residue connections available. Formula:

$$Output = F(x, \{W_i\}) + x$$

This on the ground x – Incoming information, $F(x, \{W_i\})$ – Floor output (W_i– weights), + x Residual communication, that is incoming information unchanged preserved It remains. approach ResNet grass deep models for effective does, because information layers between will not disappear and transformation process makes it easier.

EfficientNet – Efficient convolutional neuron network (CNN) architecture. EfficientNet model CNN architecture to be, to be main advantage – optimal scaling method This model is efficiency depth, width and permission done resolution at the time optimization through is increased. EfficientNet model three parameter one of time in the room increase through scaling done increases : Depth – Neuron network floors number increases. Width – Each on the floor channels number increases. Resolution done resolution – Incoming image size This approach the model only one variable according to from expansion according to more efficient to the result take is coming.

U-Net – Convolutional neuron network (CNN) architecture. U-Net is medical the images segmentation to do for CNN architecture designed for. Model Olaf Ronneberger in 2015 and his/her colleagues by working issued MRI, CT (computer tomography) medical from images organs, cells or pathologies separate to take for U-Net is based on the encoder - decoder architecture. based to divide, to divide compress, then return to original size again restoration through segmentation process done increases. U- Net advantages. High accuracy – Small also good on datasets results gives. Less calculation Requires resources – ResNet or EfficientNet such as deep models with compared to more efficient. Different in the fields usage possible – Medicine, geoinformation systems, automated image processing give. U-Net today on the day image segmentation the most effective and wide applicable from models is one.

DeepLab – Semantic segmentation for convolutional neuron network (CNN). DeepLab is the images semantic segmentation to do for used convolutional neuron network (CNN) architecture. The model is one pixel relevant to class separate, objects borders clear determination opportunity Atrous (Dilated) Convolution – Extended convolution. DeepLab Atrous Convolution (extended) or dilated convolution) technique This method uses accuracy increase for convolution the core long, wide context cover to take opportunity The Atrous Convolution formula gives:

$$y(i) = \sum_{k=0}^{K-1} x(i + r \cdot k) \cdot w(k)$$

x(i) – in the image pixel value, w(k) – filter coefficients, r – dilation rate (expansion level). Benefit. Simple to convolution relatively of the image details without loss big the field cover to take help gives. The error minimization (Loss Function). DeepLab segmentation optimization for cross - entropy loss from the function uses. Cross-entropy formula

$$L = -\sum_{i=1}^{N} y_i \log(\hat{y}_i) + (1 - y_i)\log(1 - \hat{y}_i)$$

Here – actual segmentation labels. – probability predicted by the model

Faster R-CNN – Objects determination and classification model. Faster R-CNN (Region-based Convolutional Neural Network) is objects determination and classification for used advanced model. It is a combination of R-CNN and Fast R-CNN models. developed version to be precise and speed noticeable at the level Faster R-CNN improves by two main from the stage consists of : Region Proposal Network (RPN). This part in the picture object to be possible was regions find for The bounding box of RPN objects is used. rectangle) coordinates The model determines a how many "Anchor Boxes" (ready frames) via objects searches. Fast R-CNN classifier. By RPN determined regions based on objects The model is classified as one object bounding box coordinates for and class releases.

YOLO (You Only Look Once) – Real time objects YOLO – in the image all objects one network through one once model that identifies. YOLO detection and classification together done for very fast The YOLO algorithm works. work order. Image to the grid to divide. Image into S × S grid Each grid is divided into in the territory object there is or whether there is Each grid is defined as follows : parameters prophecy does : c – Object there is or absence probability. B = (x, y, w, h) – Bounding box coordinates of the object. P – Object class probabilities (car, person, dog and hk). YOLO output {c, B, P }; c – Object existence probability. B – Object rectangle coordinates (x, y, w, h). (P) – Object probable classes (machine, person and etc.).

SSD (Single Shot MultiBox Detector) – Real time object SSD is a objects one in transfer a deterministic model. It's like YOLO fast works, but is similar to Faster R-CNN clear results gives. Convolutional layers with features separation. Model image through CNN passing, features Separates objects. determination and classification to do. Every feature map model bounding box for rectangle) and class probability The model calculates each one in the area object there is or that there is no prophecy does. Disappear function minimize. SSD object localization and reliability level optimizes. NMS (Non-Maximum Suppression) – Removes unnecessary bounding boxes take throw. Most high to probability has was objects are left, others remove is thrown. Output

$$output = \{(x, y, w, h, c, P_c)\}$$

x, y – Object center coordinates; w, h – Rectangle dimensions; *c* – Object existence probability ; P_C – Object class probability. Result. SSD more objects fast and clear determines, therefore real -time for in applications is used.

Vision Transformers (ViT) – Images via Transformer analysis ViT is based on Transformer instead of CNN. working model. He/She will take the image divided into small " patches", each one independent vector as The self-attention mechanism works. due to the model is long remote features good understands. Compared to CNN less information Transformers bigger in datasets good works.

GAN (Generative Adversarial Networks) – Artificial information create. GAN is real to the information similar new information create for The model used. GAN structure : Generative network (Generator, G). New information For example, a new face images create for usage possible. Discriminative network (Discriminator, D). Information real or artificial that The model determines the "true" and "fake" data. to differentiate is taught.

Table 1. Comparison of image processing algorithms for medical image analysis

Algorithm	Category	Performance accuracy	Notes
TYPE	Feature Extraction	85-90%	Scale and to turn resistant, very stable
HOG	Feature Extraction	75-80%	Simple and effective, but not to scale not much resistant it's not
K -means	Clustering	60-70%	In segmentation simplicity for used, low accuracy
AlexNet	CNN	70-75%	The first CNN model, today's on the day less used
VGG	CNN	85-90%	Simple and obviously, but very heavy model
ResNet-50	CNN	90-95%	Deep model, due to skip connections more precisely
EfficientNet-B0	CNN	91-94%	Low parameter, high accuracy, optimized
U-Net	Segmentation	85-90%	In biomedicine high accuracy shown
DeepLab v3+	Segmentation	90-93%	Complex structure, unclear at the borders strong
Faster R-CNN	Detection (2- stage)	91-94% MAP	Very obviously, but slowly
YOLOv5	Detection (1- stage)	88-92% MAP	Very fast, but small in facilities a little lower
SSD	Detection (1- stage)	85-89% MAP	Fast and obviously, but To YOLO than a little low

Above in the table computer see algorithms work accuracy or (according to MAP) comparison results These indicators are based on real datasets. based on taken and their to the model, to the settings looking at a little difference to do possible. Medical the images analysis to do is images again work, computer see and mechanical study methods own inside received interdisciplinary industry be, diagnosis, treatment and health observation tasks solution to do for is applied. Main approaches traditional the image again work algorithms and artificial based on intelligence (AI) modern to methods is divided (table 1).

Research to the results according to the following main to conclusions bride :

Classic methods simple images for comfortable although it is complicated in environments deep study from models efficiency in terms of behind remains.

Deep study based on models, especially CNN architectures, automatic and reliable in a way analysis to do opportunity gives.

Like YOLO, SSD and U-Net models are real -time work, object determination and segmentation in their duties high result gives.

Medical the images analysis in doing DeepLab, U-Net, and EfficientNet models accuracy and flexibility practical importance has.

Research results in the future the image again work, medical diagnostics, security systems such as in the fields effective systems create for basis to be service does.

CONCLUSION

Present at the time in medicine the images analysis to do for modern methods and algorithms active SSD (Single Shot Multibox Detector) algorithm is used. in the picture one how many the object one disposable network in passing determination opportunity gives, this and it in real time in mode to apply suitable Vision Transformers (ViT) image small into parts separate, each one to part separately attention focus through the image understanding accuracy increases. while Generative Adversarial Networks (GAN). new, realistic information create for is used, this and medical images base to expand and model training efficiency to increase help Medicine CNN (Convolutional Neural Networks) and U-Net algorithms in the field high to the results achieving, medical the images segmentation to do and pathologies in determining effective It also works in traditional methods and the car study algorithms combination medical the images analysis to do efficiency noticeable at the level increases. New technologies, in particular ViT and GAN, medical images analysis to do process acceleration and accuracy in increasing big opportunities open This gives technologies modern medical diagnostics systems working to go out help giving, quick and clear decision acceptance to do will help. In general when you get the car study and deep study with related new approaches traditional to methods relatively high efficiency provides and medicine in the field revolutionary to changes road is opening.

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