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Application of Machine Learning and Deep Learning Methods for Brain Tumor Identification and Classification

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Abstract: *In the area of medical imaging technology, advances in Artificial intelligence (AI) delivers promising solutions with higher accuracy. For healthcare solutions, medical images provides a systematic way for diagnosis the diseases earlier and make treatments more effective. Machine learning and deep learning are rapidly grown fields of AI that may apply to many domains including image processing, speech recognition and text understanding. As MRI image segmentation is a key task for identification of brain anomalies, a fast and reliable technique is essential for increasing the survival ratio of affected patients. Manual segmentation of the brain MRI image involves more time and it may subject to inaccuracies. Hence, AI approaches and algorithms have been developed for tumor segmentation. This paper contains the detailed study of the available methods of machine learning and deep learning for brain tumor identification and classification through MRI image segmentation. It discusses and summarizes the methodologies and its results available for classification of brain tumor.*

Keywords: *Classification, Convolutional Neural Network, Image Processing*

I. INTRODUCTION

Information and communications technologies (ICTs) can play a vital role in improving health care services for individuals and communities. In disease diagnosis, Medical imaging states to the set of approaches used to create images of various parts of the human body with the purpose of timely diagnosis and treatment. The influence of the medical image in healthcare is constantly growing as it provides a systematic way for diagnosis the diseases earlier and make treatments more effective.

Artificial Intelligence (AI) refers to a field of computer science that consists a set of techniques that applied to develop computerized models that performing tasks that usually require human intelligence. Machine learning (ML), a part of Artificial Intelligence paradigm, comprises techniques that make machines to learn and to solve problems without being explicitly programmed and extensively applied to medical imaging. It owns a capability of self-learning and improvisation. One of the most promising branch of ML is Deep learning (DL) that contains algorithms that makes machine "to learn" based on experience to perform the assigned task, mostly text, sound and image recognition. With the increased complexity in the medical imaging data, AI techniques plays a vital role for evolving intelligent computer vision algorithms that make computers to process, analyze, recognize and classify medical images. Recent applications of AI techniques provide impressive results in medical imaging applications. This research is aimed to study the available methods and techniques to process brain MRI images using two popular AI techniques i.e. machine learning approaches and deep learning approaches.

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II. BACKGROUND

In human body, Brain is an organ that controls all the activities that a human performs. An unrestrained group of tissue that implanted in the regions of the brain causes a Brain tumor, which eventually forms the responsive functioning of the body to be disabled. The uncontrolled growth of cancerous cells in any part of body is called tumor and when it happened in the brain, it is called brain tumor. There are two types of tumors, benign and malignant. The benign tumor normally does not have cancerous cell and having uniformity in structure, while malignant tumor contains cancerous cells and having a non-uniform structure. A biomarker is a measurable indicator and used for the diagnostic purpose. For diagnosis brain tumor and to identify biomarkers that causes brain tumor, an image technique plays a crucial role. Moreover, there are many ways available in the field of Medical imaging.

The brain is filled with soft tissues and provides better visualization [1]. MRI image of a brain provides large amount of spatial information on brain structure and it can be applied to medical diagnostics of a tumor caused in brain. MRI Brain tumors possesses several characteristics including location, size, shape, color, brightness and intensities [2][3]. In order to detect tumors and other brain abnormalities, image segmentation of brain MRI image is a very important and necessary process. Manual segmentation of the image involves more time and it is subject to inaccuracies, therefore machine learning approaches have been applied for tumor segmentation. These approaches resulted into greater efficiency.

As MRI image segmentation is a key task for identification of brain anomalies, a fast and reliable technique is essential for increasing the survival ratio of affected patients. Also, MRI image segmentation provides a set of biomarkers that are essential to classify the tumors and abnormalities developed in brain. A sample of MRI images of brain are displayed in the following figure 1.

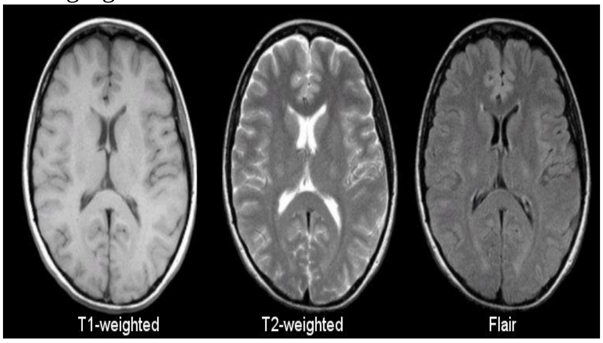

Figure 1. A sample of different MRI images

III. A PREDICTION MODEL FOR BRAIN TUMOR CLASSIFICATION USING MACHINE LEARNING APPROACH

Several researchers worked and presented their research of applying machine learning in the field of tumor identification. Many types of classifiers are also available for classification of tumor data [4]. The following figure 2 shows the common methodology follows by researchers to identify and classify brain tumor from different types of medical images. The methodology contains the steps from pre-processing to image classification. A tumor image to be input in the model and model will be classified it into either benign or malignant.

A. Pre-processing

Any machine learning algorithm requires a subsequent amount of data to train the prediction model. Therefore, relevant MRI images are required to be gathered from various sources. The most common causes for image imperfections are low contrast, distortion, low resolution, high level of noise etc. [5] Certain pre-processing techniques are then applied on MRI images that will remove the noise from images, discard the unnecessary background part from image, enhance the image quality and improve the single-to-noise ratio. Pre-processing techniques are categorized into image enhancement and image restoration. The visual representation of an image can be recovered using image enhancement techniques.

It will help to detect the objects resides in an image during image segmentation and classification [6][7]. Moreover, several techniques are available for pre-processing of an MRI image including mean filter, median filter, adaptive median filter, wiener filter etc. there are three approaches widely used for image enhancement; contrast image enhancement, color space transformation and image scaling [8]. Normally, a raw image contains various types of abnormalities, called noises, like salt and pepper speckle, poison, Gaussian, and it is required to be removed during image restoration phase [9].

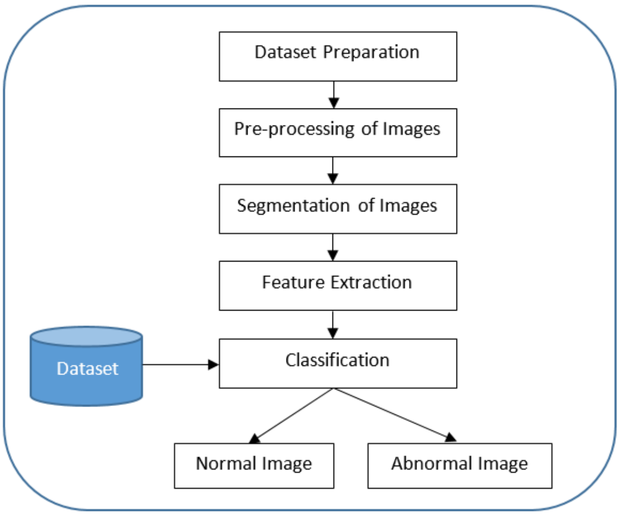

Figure 2. A Prediction Model for Brain Tumor Classification

B. Image Segmentation

After pre-processing, segmentation techniques are applied on the MRI images to identify the ROI (Region of Interest). An MRI image may contain unnecessary part and it is required to separate from the background [10]. It is further used to extract the morphological features from an image. The goal of image segmentation is to divide an image into segments having similar features or attributes. Some of the common image segmentation techniques are region-based methods, edge-based methods, clustering, thresholding, watershed methods, active contour etc. [11][12][13][14]. Each technique is having its own advantage and limitations. The following table 1 is the summary of widely used segmentation techniques.

Table 1. Widely used Segmentation Techniques

Segmentation Technique	Advantage	Disadvantage
Edge-based	Edges can be detected easily, works well when there is reasonable difference between regions in the image	Less immune to noise, not appropriate when too many edges are presented in an image.
Region-based	Good for an image containing homogeneous regions	More time consuming, memory intensive
Thresholding	Good with equal intensity images, Calculation of threshold is simple	Not suitable with illuminated variable, computationally expensive
Clustering	Eliminates noisy spots, homogeneous regions are easily obtained	Does not return the same result with each run, No. of clusters are needed to be specified
Watershed	Less time consuming and more stable results, continuous boundaries are detected	Problem of Over segmentation as there are presence of noise and other unwanted effects in the image
Active Contour	Preserves global line shapes efficiently	Accuracy is compromised with weak image boundaries

C. Feature Extraction and Classification

After an image is segmented, features can be extracted from those segmented parts. Feature is an important property of an image which is used to locate occurrence of certain object. The most common technique to find set of features are GLCM (gray level co-occurrence matrix). It has been proved one of the popular statistical method which is based on second order feature extraction.

Table 2. Summary of the work of applying machine learning for brain tumor identification and classification

Author, Year	Methodology	Dataset	Accuracy	Features
Javaria Amin et al, 2019	Gabor Wavelet Transform, Local Binary Pattern	BRATS 2013 BRATS 2015 Local Dataset	93% 97% 90%	Pixel based and Texture based features
Megha C. et al, 2019	SVM Classification	Local Dataset	83.30%	GLCM
J. Zhou et al, 2005	One-class Support Vector Machine	24 pairs of T1W and CET1W MR brain images	83.5% (Average PM)	Automatic feature extraction
Schmidt, M. et al, 2006	Soft-margin Support Vector Machine (SVM)	Dataset of 10 patients	73.20%	Four specific AB Features
Ahmed Kharrat et al, 2010	Support Vector Machine, Genetic algorithm	Dataset of 83 Images	96.29%	13 features extracted using SGLDM
E. I. Zacharaki et al, 2009	Multiclass classification	102 brain tumors image dataset	91.70%	100 features (using GLCM,Gabor, shape, statistic feature extraction techniques
P. Georgiardis et al, 2007	Probabilistic Neural Network (PNN) with LSFT	67 T1-weighted post-contrast MR images	95.24% for metastatic and primary tumors, 93.48% for gliomas from meningiomas.	36 textural features

After the extraction of the desired features, the dataset is ready to process further for classification. The prediction model is required to build that classify the image into either in a normal image or abnormal image. An abnormal image can also classify into different category that presents the severity and type of a tumor. A prediction model is build and test using suitable classifier with labelled data set during model building stage. For that, the dataset partitioned into validation dataset, training dataset and testing dataset. Machine learning models are applicable to real world problem as they possess the ability of generalization. Once a model is tested and verified, it can be used with new data which has been never seen before by the model. When new data comes, a model applied to get predicated data.
The above table 2 shows the summary of the work done by several researchers in the field of applying machine learning for brain tumor identification and classification. It contains the methodology used, the types of dataset considered during an experiment, the obtained level of accuracy and the set of features.

IV. APPLYING DEEP CONVOLUTIONAL NEURAL NETWORK FOR BRAIN TUMOR DETECTION AND CLASSIFICATION

Deep Learning is a method falls in the wider family of Machine Learning algorithms that works on the principle of learning, where learning can be supervised or unsupervised. In deep learning, a computerized model will perform specific set of classification or pattern analysis tasks based on previously learned data. Deep learning models are basically used to classify data related to images, text or sounds. It is found that, deep learning models works without human intervention and they are equivalent, and sometimes even, superior than humans. Deep learning models are always based and implemented using deep neural networks. Deep learning models needed larger datasets for computations and hence greater processing capabilities are required. The popularity of deep learning methods and approaches are due to the availability of GPU units (machines with increased chip processing abilities), cost reduction in computer hardware, and advancements in the field of machine learning algorithms. Some of the areas where deep learning models may apply are bioinformatics, medical imaging, real time object detection, industrial automation, natural language processing and many more.
Computer Vision has widespread applications in different areas agriculture surveillance, medicine, drones, and self-driving cars. The necessary part of many of these applications are visual recognition tasks such as image classification, localization and detection. Convolutional Neural Network (CNN), a type of deep learning framework is commonly used for image classification tasks including object detection, localization and classification. It learns the features automatically, removes manual feature extraction and hence eliminates the human intervention. CNN normally requires a dataset for training that is labelled and thus it is a supervised learning method inspired by animal visual cortex. Convolutional layer consists filters for applying on input image and then after the generated data is passed to the Pooling layer. Feature maps are generated at each convolution layer. It is obtained through computing convolutions between local patches and weight vectors normally called filters. Feature maps are group of local weighted sums. In order to improve the efficiency of training, filters are applied repeatedly. This process helps to reduce the number of parameters during learning process. To handle more complex features, this process is introduced and used. At last, fully connected layers are working as a regular neural network. A final learning phase maps the features to the predicted outputs. Usually, maximum deep convolutional neural networks are prepared with set convolution layers, dense layers, sub-sampling layer and soft-max layer. The general methodology of applying the deep learning models and architectures to detect, locate and predict the tumor is represented in following figure 3[22].

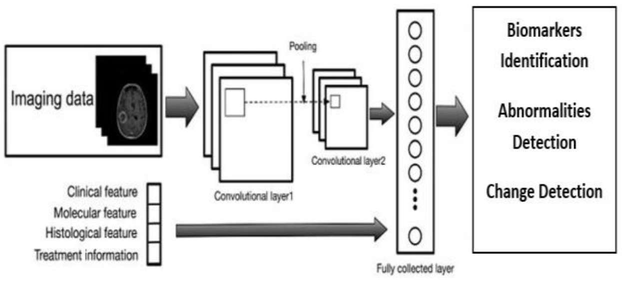

Figure 3. Deep Learning Model for analyzing brain tumor [22]

There is no need to apply segmentation and feature extraction techniques separately, as deep learning models eliminates the manual extraction of the features. The output can be in several forms including biomarkers identification, abnormalities detection, change detection between two images etc. The phases for experimenting and implementing the deep learning models are a) Dataset Preparation of Brain MRI Images; b) Identification and Deployment of Convolutional Neural Network (CNN) Model; c) Train, Validate and Test Model; d) Accuracy and Performance Measurement; e) Prediction on unseen Data (Introducing unseen MRI image and prediction). Several models based on CNN are proposed and implemented by many researchers. The major CNN models includes LeNet, AlexNet, ZFNet, GoogleNet, VGGNet and ResNet. The following table 1 illustrates the summary of the various CNN models discussed previously in the paper. It contains the CNN model, its inception, whom developed, top-5 error rate, number of parameters used to train the network, the time taken to train the network.

A. Comparative Analysis of CNN Models

The following table 3 illustrates the summary of the various CNN models discussed previously in the paper. It contains the CNN model, its inception, whom developed, top-5 error rate, no. of the parameters for training of the network, the time taken to train the network [23] [24] [25].

Table 3. Details of CNN Models

Year of Inception	CNN Model	Time taken to Train the Model	Top-5 error rate
2015	ResNet	Either Two to three weeks (8 GPU machines)	3.6%
2014	VGGNet	Either Two to three weeks (4 Nvidia Titan Black GPUs)	7.3%
2014	GoogleNet	Week (few high-end GPUs)	6.7%
2013	ZFNet	Twelve days (GTX 580 GPU)	14.8%
2012	AlexNet	Five to six days (Two GTX 580 GP)	15.3%
1998	LeNet	--	--

B. Transfer Learning

Deep learning models require a huge dataset, advanced computational resources and time to train. Transfer learning utilize a knowledge acquired for one task to solve another task. It is the utilization of pre-trained models for performing similar task using parameter fine-tuning. It is used when the dataset available for training is small and there is an availability of pre-trained models to solve the problem. This approach is widely adoptable to solve the computer vision related problems. The below figure 4 shows how transfer learning works.

It is very common to work with ImageNet data as an input for transfer learning. The final layers are to be freeze and weights are transfer to the other CNN model with specific dataset. It will then generate final classification output.

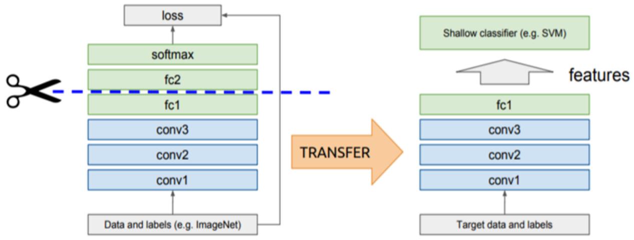

Figure 4. Working of Transfer Learning [28]

Several researchers applied the different types of CNN models for locating and predicting brain tumors as shown in following table 3. The table contains the algorithm used, the dataset considered for experiment and the accuracy obtained during an experiment.

Table 3. Deep learning models for brain tumor detection and classification

Author, Year	Method	Dataset	Accuracy
Ercan et al, 2019	Faster R-CNN	3064 MRI brain images	91.66%
Fabian Isensee et al, 2018	U-Net	BRATS-2015	85%
Manjunath S et al, 2019	ANN, CNN	370 images	73. 6486% and 86. 4865%
Parasuraman Kumar et al, 2019	Ensemble classifier	30,000 Images	91.17%

V. COMPARISON BETWEEN MACHINE LEARNING AND DEEP LEARNING APPROACHES

Machine learning algorithms provide good result with small datasets. Hence, it is also easy to train the model quickly. In addition, less computational resources are required to train the model i.e. it can be trained on CPU itself. In machine learning, features are required to extract manually. Therefore, it is required to try different set of features and classifiers before evolving a final prediction model. In consideration with hyper-parameter tuning, it has limited tuning capabilities. Deep learning algorithms required huge dataset and hence, it takes more time to train the model. Moreover, it requires more computational resources and GPU are mostly needed. There is no need to extract the features manually, and it learns the features and classifiers automatically.

It has unlimited accuracy and transfer learning gives a new height in terms of prediction capabilities. The following table 4 represented the major differences between two approaches.

Table 4. Comparison between Machine Learning and Deep Learning Approaches

Parameter	Machine Learning	Deep Learning
Hardware Dependency	Train on CPU	Train on GPU
Dataset required and Performance against data	Small dataset required Works well when dataset is small	Huge dataset required Works well though data volume increases
Feature Selection and Extraction	Hand-coded features respective to domain and dataset type	Automatic feature selection and extraction, transfer learning is also available
Execution Time	Small time to train	Long time to train

VI. CONCLUSION

In this paper, a partial survey for application of machine learning and deep learning techniques for brain tumor detection and classification is performed. In a first half, the paper summarizes the detail about the image pre-processing, segmentation and classification of brain MRI images. It also represented the research carried out regarding application of different classifiers for brain tumor detection. The rest of the paper contains the description of types of deep learning models, application of CNN for brain tumor detection and classification and the summary of research work carried out by various researchers for the said area. It will provide the fruitful insights to the researchers working in the same area.

REFERENCES

1. Villanueva-Meyer, J. E., Mabray, M. C., & Cha, S., Current Clinical Brain Tumor Imaging, Neurosurgery, Volume 81, Issue 3, pp. 397–415, 2017
2. Evangelia I Zacharaki, Sumei Wang, Sanjeev Chawla, Christos Davatzikos, Classification of brain tumor type and grade using MRI texture in a Machine Learning technique, Magnetic Resonance in Medicine, Volume 62, Issue 6, pp. 1609-18, 2009
3. Zhao Junting, Meng Zhaopeng, Wei Leyi, Sun Changming, Zou Quan, Su Ran, Supervised Brain Tumor Segmentation Based on Gradient and Context-Sensitive Features, Frontiers in Neuroscience, Volume 13, Pages 144, 2019
4. Jyotsna Dogra, Shruti Jain, Meenakshi Sood, Glioma Classification of MR Brain Tumor Employing Machine Learning, International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-8 Issue-8, June 2019
5. Sheela.V.K., Dr. S. Suresh Babu, Pre-Processing Technique for Brain Tumor Detection and Segmentation, International Research Journal of Engineering and Technology (IRJET), Volume: 02 Issue: 03 | June-2015
6. Dr.K.Thangadurai, K.Padmavathi, Computer Vision image Enhancement for Plant Leaves Disease Detection, World Congress on Computing and Communication Technologies, IEEE, pp. 173-175, 2014
7. S.S. Agaian, K.P. Lentz, A.M. Grigoryan, A New Measure of Image Enhancement, International Conference on Signal Processing & Communication, pp. 19–22, 2000
8. Isha Patel, Sanskruti Patel, Atul Patel, Analysis of Various Image Preprocessing Techniques for Denoising of Flower Images, International Journal of Computer Sciences and Engineering, Vol.-6, Issue-5, pp. 1012-1018, May 2018
9. Sheikh Tania et. al, A Comparative Study of Various Image Filtering Techniques for Removing Various Noisy Pixels in Aerial Image, International Journal of Signal Processing, Image Processing and Pattern Recognition, 9(3), 2016
10. Anelia Angelova et. al, Image segmentation for large-scale subcategory flower recognition, IEEE, 2013
11. Asma Najjar, Ezzeddine Zagrouba, Flower image segmentation based on color analysis and a supervised evaluation, IEEE, 22 May 2014, pp. 402-406.
12. Nida M. Zaitoun et. Al, Survey on Image Segmentation Techniques, International Conference on Communication, Management and Information Technology, Science Direct, 2015.
13. Isha Patel, Sanskruti Patel, Flower Identification and Classification using, Computer Vision and Machine Learning, Techniques, International Journal of Engineering and Advanced Technology, Volume-8 Issue-6, August 2019, pp. 277-285
14. Javaria Amin, Muhammad Sharif, Mudassar Raza, Tanzila Saba, Muhammad Almas Anjum, Brain tumor detection using statistical and machine learning method, Computer Methods and Programs in Biomedicine, Volume 177, 2019, Pages 69-79
15. Megha C., Sushma J. (2019) Detection of Brain Tumor Using Machine Learning Approach. In: Singh M., Gupta P., Tyagi V., Flusser J., Ören T., Kashyap R. (eds) Advances in Computing and Data Sciences. ICACDS 2019. Communications in Computer and Information Science, vol 1045. Springer, Singapore
16. Janki Naik, Sagar Patel, Tumor Detection and Classification using Decision Tree in Brain MRI, IJCSNS International Journal of Computer Science and Network Security, VOL.14 No.6, June 2014, pp. 87-91
17. J. Zhou, K. L. Chan, V. F. H. Chong and S. M. Krishnan, "Extraction of Brain Tumor from MR Images Using One-Class Support Vector Machine," 2005 IEEE Engineering in Medicine and Biology 27th Annual Conference, Shanghai, 2005, pp. 6411-6414.
18. Schmidt, M., Levner, I., Greiner, R., Murtha, A., & Bistritz, A. (n.d.). Segmenting Brain Tumors using Alignment-Based Features. Fourth International Conference on Machine Learning and Applications (ICMLA'05). doi:10.1109/icmla.2005.56, 2006
19. Ahmed Kharrat, Karim Gasmi, Mohamed Ben Messaoud, Nacéra Benamrane and Mohamed ABID, Hybrid Approach for Automatic Classification of Brain MRI Using Genetic Algorithm and Support Vector Machine, Leonardo Journal of Sciences ISSN 1583-0233, Issue 17, July-December 2010 p. 71-82
20. E. I. Zacharaki, S. Wang, S. Chawla, D. S. Yoo, R. Wolf, E. R. Mehem, C. Davatzikos, Classification of brain tumor and grade using MRI texture in a Machine Learning technique, (Magn. Reson. Med. 62(2009)), pp. 1609–1618.
21. P. Georgiardis, D. Cavouras, I. Kalatzis, G. C. Kagadis, M. Malamas, G. Nikifordis, E. Solomou, Nonlinear least square feature transformations for improving the performance of probabilistic neural networks in classifying human brain tumors on MRI, (LectureNotesinComputerScience4707(2007)),pp. 239–247.
22. M. Zhou, J. Scott, B. Chaudhury, L. Hall, D. Goldgof, K.W. Yeom, M. Iv, Y. Ou, J. Kalpathy-Cramer, S. Napel, R. Gillies, O. Gevaert and R. Gatenby, Radiomics in Brain Tumor: Image Assessment, Quantitative Feature Descriptors, and Machine-Learning Approaches, American Journal of Neuroradiology, 39 (2) 208-216 2018
23. Alom, Md. Zahangir & M. Taha, Tarek & Yakopcic, Christopher & Westberg, Stefan & Hasan, Mahmudul & C Van Esesn, Brian & Awwal, Abdul & Asari, Vijayan, The History Began from AlexNet: A Comprehensive Survey on Deep Learning Approach, 2018
24. Evolution of CNN Architectures: LeNet, AlexNet, ZFNet, GoogleNet, VGG and ResNet, https://iq.opengenus.org/evolution-of-cnn-architectures/
25. https://adeshpande3.github.io/The-9-Deep-Learning-Papers-You-Need-To-Know-About.html
26. Ercan avşar, kerem salçin, "Detection and Classification of Brain Tumours From MRI Images Using Faster R-Cnn", Tehnički Glasnik 13, 2019.
27. Fabian Isensee, Philipp Kickingereder, Wolfgang Wick, Martin Bendszus, and Klaus H. Maier-Hein, "Brain Tumor Segmentation and Radiomics Survival Prediction: Contribution to the BRATS 2017 Challenge", arXiv:1802.10508v1 [cs.CV] 28 Feb 2018
28. Dipanjan (DJ) Sarkar, A Comprehensive Hands-on Guide to Transfer Learning with Real-World Applications in Deep Learning, https://towardsdatascience.com/a-comprehensive-hands-on-guide-to-transfer-learning-with-real-world-applications-in-deep-learning-212bf3b2f27a retrieved on December 2019.

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