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A Research Survey on Computer Aided Diagnosis of Ischemic Stroke Detection Using CT and MRI Images

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Abstract: Stroke or cerebrovascular accident is the most leading neurological syndrome and ranks three of all the human brain abnormality. The commencement of neurological symptomatology includes hemiparesis, aphasia, and hemianopia. If any blockage of blood flow or rupture of an artery to the brain occurs, then that result in lack of oxygen which results in sudden demise of the brain cells tends to Stroke. To detect and locate the type and status of stroke, the highly recommended modalities by the physicians are Computed Tomography (CT) and Magnetic Resonance Imaging (MRI). It is a great challenging task for the physicians to locate the acute lesions from CT and MRI, thus an elegant event can be developed. Developing such a smart computer aided automated method will sure help in locating such acute lesions. A clean review on stroke and all its technical detecting modalities and methods are analyzed to develop a computer aided approach to detect acute lesions. These sort of computer aided stroke detection acts well in identifying the normal and abnormal tissues in human brain.

Keywords: Stroke, CT, MRI, lesion, Medical imaging, Perfusion imaging, lesion detection, Computer aided method.

Introduction

The father of medicine, Hippocrates initiated the stroke history, which was first documented some 2,400 years ago. Similar to heart attack, Stroke is a brain attack caused by a lack of blood supply to the brain. The brain is jam-packed with neurons which make the brain work. For efficient working and survival they need constant blood supply. The brain is divided into two hemispheres, the right and the left. The right hemisphere of the brain is in command of the left side of the body. The left hemisphere of the brain is in command of the right side of the body. Some functions are controlled by both. The commencement of neurological symptomatology includes hemiparesis, aphasia, and hemianopia. Cerebrovascular accident (CVA), cerebrovascular insult (CVI), brain attack are the others names to stroke occurs due to worst blood flow to the nervous system which results in brain cell decease. Signs and symptoms of stroke includes head ache, vomiting, vertigo, loss of consciousness, sudden loss of speech, weakness, inability to move, problems in understanding and speaking, sensation that the world is spinning and loss of vision to one side. The symptoms of a stroke can be permanent and protracted journey impediment may embrace pneumonia or loss of bladder control.

Due to this brain attack, stroke patients are left with physical illness, emotional strain, depressive burden on family members. The real cost in planning research on stroke involves recruiting stroke patients and collecting data. The point to encourage in survey on stroke requires adequate number of sample sizes to demonstrate the issues. [1] Robot-aided stroke rehabilitation is the current approach which can be implemented for the stroke survivors. With the ideas of clinical experts, optimally designed control system can be developed that helps robotic arm by means of position, velocity and forces. [2] As per American Heart Association, every 40seconds somebody is affected by stroke. The goal of this study is to come out with the clinical practices of stroke from various hospitals. [3]

Milieu

Two main types of stroke are Ischemic and Hemorrhagic stroke. Ischemic stroke (clots) arises whenever there is an obstacle in the artery which supplies blood to the brain. Due to the deposition of the fats coating the blood vessel walls, this obstacle occurs. These fatty acids results in two cases of obstacles. It accounts for 87% of all stroke cases. Substance namely plague builds up on the inner wall of the artery entirely responsible for blockage. The blockage or clot matures as blood cells and fat cells stick to the plaque. Progressively, it nurtures large enough to block customary blood flow. Cerebral thrombosis is the blood clot in the blocked area of the blood vessel. Cerebral embolism is sudden blocking of an artery by a clot of strange substances. If a patient with a complaint of ischemic stroke reaching the hospital within the 4.5 hours of onset, then the recommended dose for that patient is tissue plasminogen activator (tPA). [4], [8]

Hemorrhagic stroke (bleeds) arises whenever there is burst because of weakened blood vessels. It accounts for 15% of all stroke cases. This bleeding results in two cases as aneurysms and arteriovenous malformations (AVMs). Transient Ischemic Attack (TIA) is because of a momentary clot can also be called as a ‘mini stroke’. TIA symptoms strength last only for a few minutes or hours. No lasting damage occurs, but this sort of warning strokes should be taken awfully serious. If a question asked to a man with a symptom of stroke, though he knows the answer, he could not

come out with appropriate words and the physician will get only unintelligent and amusing answers. [5]

Different modalities of brain images are CT, MRI, Positron Emission Tomography (PET), Ultrasound etc. Of the various existing modalities CT is the utmost common, because of its reduced cost and time. In CT images, dark regions denote ischemic stroke and bright regions denote hemorrhage stroke. Ischemic and hemorrhagic stroke are to be treated differently. After the onset of the stroke, it should be treated within three hours, else it may result in permanent disability or death. [21] Due to the limitations in CT, if physicians recommend for MRI, then the patient will undergo MRI which is costly and time consuming.

A review was carried on current CT and MRI methods applied to manage the stroke patients. The advantages and disadvantages of these techniques were discussed. Of which major drawback of modern CT is high radiation dose and while MRI is more complicated. With these techniques it is possible to separate patients at risk of infarct growth. [6] CT images are the popularly used modality because of its faster processing, avoiding faults and aptness with physicians and radiologist. [7]

Life after Stroke

As per Heart and Stroke Foundation survey a report on stroke implies:

- One in two having a close friend or family member as a stroke survivor.
- One in five honestly concerned in support and care of a stroke survivor.
- Two in three accept as truethat the majority of strokes can be prevented.
- One in five believes that most strokes are terminal.
- Four in five believe that stroke survivors can be in good health and lead normal life.
- One in six stroke survivors can't do anything to prevent it.
- One in threebelieves that chances are there for stroke survivors to recover only in the initial three months of their onset else can't be recovered anymore. [9]

The "Implementation Strategies for Emergency Medical Services within Stroke Systems (EMSS) of are" policy statement outlines specific parameters that measure the quality of an EMSS, including the following: On receiving the call from the stroke patients, response time from the stroke unit should be less than 90 seconds. And EMSS response time should be less than 8 minutes. Time taken to shift and turnout is 1 minute. The on-scene time is less than 15 minutes. Travel time is equal to trauma or myocardial infarction calls. [10]

Computer aided stroke detection methods using CT

An automated detection method was proposed to locate the Middle Cerebral Artery (MCA) dot sign (thromboembolous) of acute stroke on unenhanced CT images. Five steps have been followed in this method namely: extraction of the sylvian fissure region, MCA dot identification using top-hat transformation, candidate for extraction, classifying candidates using SVM, using rule-based scheme to avoid false positive.[11] Brain damage occurs as a result of severe blood circulation failure and this reduced blood flow can be detected using Non Contrast Computed Tomography (NCCT). To quantify the early ischemic changes (EICs), the Alberta Stroke Program Early CT score (ASPECTS) scoring method was used. An automated brain densitometric method was developed to divide CT scans of the brain using atlas based segmentation. This method was optimized and validated using CT data from 10 to 63 patients. This automated ASPECTS method can be used as a tool to assist manual scoring. [12]

A phantom study to estimate the prognosis of thrombolysis was done using CT. Because CT appeared feasible to differentiate thrombi, five groups of thrombi are considered for testing. Output of this study revealed that CT is a suitable technique in estimating the portion of erythrocytes within vitro thrombi. [13] A fully automated tool was developed allowing CT brain image preprocessing on healthy and stroke patients. Method was validated using CT image database collected for the Birmingham University Cognitive Screen (BUCS) and obtained from units across West Midlands of United Kingdom. [14] To evaluate the blood circulation in brain for stroke patients, important techniques used are CT perfusion (CTP) imaging and MR perfusion (MRP) imaging. The computed assisted diagnosis system was legalized on 75 triplet medical images with the symptoms of ischemic stroke. Each triplet was provided with Cerebral Blood Flow (CBF) and Cerebral Blood Volume (CBV) map and plain CT image for validation. [15]

Parameters calculated to study the multi-delay multi-parametric pseudo-continuous arterial spin labeling (pCASL) protocol were Arterial Transit Time (ATT), Mean Transit Time (MTT), CBF, and CBV. This study on the various parameters revealed the possibility for the patient affected by acute stroke. [16] In order to diagnose the ischemic stroke early a popular multiscale transform namely Laplacian transform is used, which decomposes the CT image. The desired feature extracted by this is the sensitive stroke area and enhanced by modification in decomposition coefficients. Parameters such as sensitivity, specificity, positive predictive value, negative predicate value are tabulated with the help of neurologists who gave the result as 6 patients with greater facilitation, 19 patients with modest facilitation and nine with no facilitation. [17]

Cellular automata a power tool in various fields of cryptography meantfor segmenting process using CT images. DeCas- teljau method was used to plot the Beizer curve, by which points other than midpoints are plotted. To analyze the texture value the statistical method used is covariance matrix in the name of Gray Level Covariance matrix (GLCM) and support vector machine as a classifier. In general, each pixel corresponds to one of the four cases as true positive correctly classified as positive pixels, false positive incorrectly classified as negative pixels, true negative correctly classified as negative pixels, false negative incorrectly classified as positive pixels. Based on the four categories, precision, sensitivity and specificity are calculated. [18] A package of image enhancement, detection of midline symmetry and classification of abnormal slices modeled a method to monitor

the ASPECTS score to determine the coverage of ischemic stroke on brain CT images. Anglia Ruskin Clinical Trials Unit (ARCTU) autonomously conducted a quantifiable exploration of the e-ASPECTS software, an automated scoring system coupled with diagnostic ischemic stroke patients, to help the neurologists for elucidation. [19]

An excellent computer aided diagnosis system was developed to help the radiologists to diagnose brain stroke which performs it work on CT database with discrete wavelet transform, GLCM for feature extraction, Genetic algorithm(reproduction, cross over and mutation are the operators used for production of next generation from the current generation) for feature selection, support vector machine as classifier. [20] Brain tissue edges around the stroke area are often unidentified by the inexperienced radiologists. To make out such little tissue edges, efficient ischemic stroke detection method was developed. Such method contains cubic curve equations for preprocessing, Gaussian kernel functions for brain tissue extraction, brain area segmentation and partitioning for graywhite matter interface(probable region for stroke), an unsupervised region growing algorithm (URGA) for edge detection. Parameters such as specificity, precision, decision rate, false alarm rate, correction classification rate are tabulated. [21]

To improve the detectability of early infract signs of delicate ischemic stroke, a method was developed which helps in framing computer aided detection system. Adaptive partial smoothing filter (APSF) was formulated to reduce noise and to preserve edges. APSF based simulation was applied to number of clinical CT scans to detect the stroke signs. [22] The proposed automated method in this paper explains the preprocessing, segmentation, extraction of texture features and classification. This proposed method of early detection of ischemic stroke improved the efficiency and accuracy of clinical practice. An accuracy of 98%, 97%, 96% and 92% obtained in this automated method using SVM, k-NN, ANN and decision tree classifiers [23], [24] With the concept of ANN, computer medical model can be designed with soft and hard inputs. To develop a classification model, NN based four different algorithms were studied and analyzed. [25] CT brain images were given as input to the SVM which was then compared with the prognostication tools which uses the SEDAN (**S**ugar, **E**arly Infarct signs, **D**ense cerebral artery sign, **A**ge, **N**ational Institute of health stroke scale on admission) and HAT (**H**aemorrhage **A**fter **T**hrombolysis) scores. To provide treatment to Symptomatic Intracranial Haemorrhage (SICH), these analyses with SEDAN and HAT was done. [26]

Computer aided stroke detection methods using MRI

Using multimode MRI data, an active learning selective sampling approach was developed which supports voxel based lesion segmentation. Classifier used here is random forest classifier. [27] To detect cerebral microbleeds (CMB), a computer aided detection system was developed which involved three steps as skull stripping, initial candidate selection and reduction of false positives. [28] MRI which provides high resolution supports well for soft tissue characterization. This algorithm explains the digital image processing tools for the location of infract and hemorrhage in brain. This method detects the stroke and also defines that MRI is superior to CT in stroke detection. [29]

Commonly used techniques to detect brain tumors are CT and MRI. Of the two MRI is the best method which gives the high quality imaging, shows contrast for soft tissues. In this GLCM delivers 14 texture features in the name of the following metrics (a)angular second moment, (b)contrast, (c)correlation, (d)sum of squares: variance, (e)inverse difference moment, (f)sum average, (g)sum variance, (h)sum entropy, (i)entropy, (j)difference variance, (k)difference entropy, (l) and (m) a pair of information measures of correlation (in Shannon's sense), (n) maximal correlation coefficient. These data's are extracted from the MRI slices and classifies with SVM. [30]

For the detection of cerebral ischemic stroke a novel framework was designed which is well in detecting the ischemic stroke using MRI images. Three brain injury detection methods such as Symmetry Integrated Region Growing (SIRG), Hierarchical Region Splitting (HRS) and Modified Watershed Segmentation (MWS) were compared which supports well in developing the defined framework. [31] Due to the intensity matching between brain lesions and normal tissues, multispectral MRI modalities were used for brain lesion detection. Histogram-based gravitational optimization algorithm (HGOA) is proposed to analyze histogram results using enhanced gravitation optimization algorithm. The developed optimization algorithm segments brain into different number of regions labeling as normal and abnormal. The ischemic stroke lesions and tumor lesions are segmented with 91.5% and 88.1% accuracy. [32]

Patients with mitochondrial myopathy, encephalopathy, lactic acidosis andstroke-like episodes (MELAS) expected to have stroke-like episodes (SEs). A study on cerebral hyperfusion perceived on atrial spin labeling (ABL) perfusion magnetic resonance imaging stated that preclinical phase identified the onset of SEs, 3 months before in 3 MELAS patient MRIs. Conventional MRI didn't detect the hyperfusion area but ASL imaging has the ability to locate the SEs. [33] A 3-D lesion detection method was proposed due to the high cost of MRI and patients critical conditions to collect multiple images. This approach required only a single type of anatomical MRI scan. In the presence of lesions, voxel-intensity based segmentation and the spatial location based tissue distribution were irregular in the areas of lesions. The degree of this irregularity on calculation states the likelihood of tissue abnormality. [34] Since White matter lesion (WML) is a term related to stroke and carotid disease, exact volume measurement is most essential. The white matter lesion segmentation scheme for fluid attenuation inversion recovery (FLAIR) MRI was discussed to compute the volume of lesions and sub voxel precision by considering partial volume averaging (PVA). The WML study on each brain hemisphere was treated separately using lesion load analysis. [35]

A multimodal Markov random field model was proposed which included all MR modalities. The results of this multimodal method were then compared with those obtained with mono-dimensional segmentation. An atlas of

blood supply territories to help physician to determine the subtypes of stroke was constructed. [36] The GLCM method was used for image feature calculation after preprocessing. After the application of wavelet transform, the coefficients are given as the input to the neural networks to distinguish normal and abnormal images. [37], [7] MRI images are preprocessed to remove the multiplicative noises and using bifurcation analysis the midline of the brain is exacted. Classification model to detect ischemic stroke was developed using the Artificial Neural Network. Finally to locate the area of lesion fuzzy C-Means segmentation is used which produces the accuracy of 94.43%. [38] The fully automatic system designed accurately segments brain tumor using Gabor wavelet features with the help of several classifiers. Redundancy in Gabor wavelet makes the computation low and it requires more memory. [39]

For the valuable treatment, information related to the location of the lesion is necessary. Hence a fully computerized automatic system to quote the lesion area is therefore obligatory. Such system is designed with the neuro fuzzy inference system (ANFIS) with the help of automatic seed point assortment. Similarity Index (SI), Overlap fraction (OF), Extra Fraction (EF) and positive predictive value (PPV) are the criteria's concerned for tumor segmentation. With the enough knowledge of the brain tissue patterns, this work on brain lesion segmentation can be extended for stroke lesions. [40] The proposed computer aided diagnosis system enhances physician's capability to diagnose and reducing time needed for the accurate diagnosis. This technique involves the computational method such as feedback pulse coupled neural network for image segmentation, discrete wavelet transform for feature extraction, the principal component analysis for reducing the dimensionality of the wavelet coefficients and feed forward back propagation neural network for the classification of normal and abnormal images. [41]

With the help of multi parametric 2D MR images of brain a fully automated pathological area extraction method was developed. Otsu's algorithm was used to determine the threshold for feature extraction. This method works on symmetry and evaluated by Dice coefficient. [42] Tool used for the early ischemic changes after stroke based on location and extent of stroke lesion is Alberta Stroke Program Early CT Score (ASPECTS). To develop a tool for large scale analyses and to reduce inter rater variability and slice orientation differences, MR topographical score (MR-TS) is automated. Using these auto-MR-TS 29 patients was evaluated. These auto-MR-TS afford the measure of stroke brutality in an automated approach. [43]

Conclusion

In this survey, types and status of strokes are studied. Any smart and very effective computer aided model can be designed to predict the stroke well in advance to avoid permanent disability. Such model not only predicts the stroke, also saves life. With the help of CT and MRI modalities, the model can bring out their results in bringing out how well the lesion identified is of stroke and free from stroke. An advanced intelligent computer aided diagnosis system can be developed with the knowledge based classification techniques such as neural networks, fuzzy logic, etc.

References:

[1]Leah Jeffries, Karen Grimmer-Somers, Julie, "Practical Aspects of repeated measures stroke research: Recruitment, Resources, Time frames and Survey instruments", The internet journal of allied health sciences and practice, vol 7, no.1, pp. 1-10, 2009.

[2]Pradeep Natarajan, Ashley Oelschlager, Arvin Agah, Patricia S.Pohl, S.Omar Ahmad, Wen Liu, "Current clinical practices in stroke rehabilitation: Regional pilot survey", Journal of Rehabilitation Research and Development, vol 45, no.6, pp. 841-850, 2008.

[3]Mylene Schriner, Janell Thome,"Rehabilitation of the upper extremity after stroke: Current Practice as a guide for curriculum", The Open Journal of Occupational Therapy, vol 2, no.1, pp. 1-14, 2004.

[4]Bruce C.V.Campbell, Nawaf Yassi,Henry Ma, Gagan Sharma, Simon Salinas, Leonid Churilov, AtteMetetoja, Mark W.Parsons, Patricia M.Desmond, Maarten G.Lansberg, GeofferyA.Donnan, and Stephen M.Davis, "Imaging selection in ischemic stroke: feasibility of automated CT-perfusion analysis", International Journal of Stroke, Research, Worlds Stroke Organization, vol. 10, no. 1, pp. 51-54, 2015.

[5]Low Chen Hoong, Vijay K. Sharm, "Journey During Acute Ischemic Stroke: A Physician's Experience", Annals of Family Medicine, vol. 8, no. 3, pp. 265-267, 2010.

[6]Josef Vymazal, Aaron M.Rulesh, Jifi Keller, LadislavaJanouskova, "Comparison of CT and MR imaging in ischemic stroke", Insights Imaging, Springer, vol. 3, no. 6, pp. 619-627, 2012.

[7]P. Shantha Kumar and P. Ganesh Kumar, "Performance analysis of brain tumor diagnosis based on soft computing techniques", American Journal of Applied Sciences, vol. 11, no. 2, pp. 329-336, 2014.

[8]Guillaume Turc,MD; Marion Apoil, MD; Olivier Naggara, MD, PhD; David Calvet, MD, PhD; Catherine Lamy, MD; AlinaM.Tataru, MD; Jean-Francois Meder, MD, PhD; Jean-Louis Mas, MD; Jean-Claude Baron, MD, ScD, FMedSci; Catherine Oppenheim MD,PhD; Emmanuel Touze, MD, PhD , "Magnetic Resonance Imaging-DRAGON Score 3-Month Outcome Prediction After Intravenous Thrombolysis for Anterior Circulation Stroke", Journal of the American Heart Association, vol. 44, no. 5, pp. 1323-1327, 2013.

[9] www.heartandstroke.com.

[10]Edward C. Jauch, MD, MS, FAHA, Chair; Jeffrey L. Saver, MD, FAHA, Vice Chair;Harold P. Adams, Jr, MD, FAHA; Askiel Bruno, MD, MS; J.J. (Buddy) Connors,

MD;Bart M. Demaerschalk, MD, MSc; PoojaKhatri, MD, MSc, FAHA; Paul W. McMullan, Jr, MD, FAHA; Adnan I. Qureshi, MD, FAHA; Kenneth Rosenfield, MD, FAHA; Phillip A. Scott, MD, FAHA; Debbie R. Summers, RN, MSN, FAHA; David Z. Wang, DO, FAHA; Max Wintermark, MD; Howard Yonas, MD, "Guidelines for the Early Management of Patients With Acute Ischemic Stroke",Journal of the American Heart Association, Stroke, vol. 44, no. 3, pp. 870-947, 2013.

[11]Noriyuki Takahashi, Yongbum Lee, Du-Yih Tsai,Eri Matsuyama, Toshibumi Kinoshita, Kiyoshi Ishii, "An automated detection method for the MCA dot signof acute stroke in unenhanced CT. Radiol Phys Technol, vol. 7, no. 1, pp. 79–88, 2014.

[12]Berend C. Stoel, Henk A. Marquering, Marius Staring, Ludo F. Beenen, Cornelis H. lumpYvo B. Roos, Charles B. Majoie, "Automated brain computed tomographic densitometry of early ischemic changes in acute stroke", Journal of Medical Imaging vol. 2, no.1, pp. 014004-1-11, 2015.

[13]Klaus Kirchhof, MD, Thomas Welzel, MD, Cora Mecke, SaidaZoubaa, MD, Klaus Sartor, MD, "Differentiation of White, Mixed, and Red Thrombi: Value of CT in Estimation of the Prognosis of Thrombolysis—Phantom Study. Radiology; vol. 228, no. 1, pp. 126–130, 2003.

[14]C´eline R.Gillebert, Glyn W. Humphreys, Dante Mantini, "Automated delineation of stroke lesions using brain CT images". NeuroImage: Clinical vol 4, pp. 540–548, 2014.

[15]T.Hachaj and M.R.Ogiela, "CAD system for automatic analysis of CT perfusion maps", OPTO−ELECTRONICS REVIEW, vol 19, no. 1, pp. 95-103, 2011.

[16]Danny J.J. Wang , Jeffry R. Alger, Joe X. Qiao, Matthias Gunther, Whitney B. Pope, Jeffrey L. Saver, Noriko Salamon, David S. Liebeskind, "Multi-delay multi-parametric arterial spin-labeled perfusion MRI in acute ischemic stroke — Comparison with dynamic susceptibility contrast enhanced perfusion imaging", Elseiver NeuroImage: Clinical, Volume 3, pp. 1–7, 2013.

[17]Mehdi Sajjadi, Mehdi Karami, RassoulAmirfattahi, VahidBateni, Mohammad R. Ahamadzadeh, and BaharehEbrahimi, "A promising method of enhancement for early detection of ischemic stroke", Journal of research in medical sciences, vol. 17, no. 9, pp. 843–849, 2012.

[18]Teena Thomas, Jobin Jose, "Computer aided detection of ischemic stroke using cellular automata", International Journal of Innovative Research in Science, Engineering and Technology, vol. 3, no. 5, pp. 146-150, 2014.

[19]James Hampton-Till, Michael Harrison, Anna Luisa Kühn, Oliver Anderson, Devesh Sinha, Sharon Tysoe, Eric Greveson, Michalis Papadakis, Iris Q. Grunwald,"Automated quantification of stroke damage on brain computed tomography scans: e-aspects". European medical journal, pp. 1-6, 2015.

[20]Ali Shalikar, Mohammad Reza Ashouri and Mohammad HosseinNadimiShahraki, "A CAD System for Automatic Classification of Brain Strokes in CT Images", International Journal of Mechatronics, Electrical and Computer Technology, vol. 4, no. 10, pp. 67-85, 2014.

[21]Yeu-Sheng Tyan, Ming-Chi Wu, Chiun-Li Chin, Yu-Liang Kuo,Ming-Sian Lee and Hao-Yan Chang, "Ischemic Stroke Detection System with a Computer-Aided Diagnostic Ability Using an Unsupervised Feature Perception Enhancement Method", International Journal of Biomedical Imaging, vol. 2014, Article ID 947539, pp. 1-12, 2014.

[22]Yongbum Lee, Noriyuki Takahashi, Du-Yih Tsai, Hiroshi Fujita, "Detectability improvement of early sign of acute stroke on brain CT images using an adaptive partial smoothing filter. Medical Imaging, vol. 6144 61446Q- pp. 1-8, 2006.

[23]G.seshamma, T.Anandbabu, "Performance analysis of ischemic stroke using soft computing techniques", International journal of computer science information and engg, vol. 3, no. 4, pp 1-12. 2014.

[24]N.HemaRajini, R.Bhavani, "Computer aided detection of ischemic stroke using segmentation and texture features", Elseiver, Measurement, vol. 46, no. 6, pp. 1865–1874, 2013.

[25]R.Karthik, R.Menaka, Siddharth Kulkarni and Rahul Deshpande, "Virtual doctor: an artificial medical diagnostic system based on hard and soft inputs", Int. J. Biomedical Engineering and Technology, vol 16, no. 4, pp. 329-342, 2014.

[26] Paul Bentley , Jeban Ganesalingam, Anoma Lalani Carlton Jones, Kate Mahady, Sarah Epton, Paul Rinne, Pankaj Sharma, Omid Halse, Amrish Mehta, Daniel Rueckert , "Prediction of stroke thrombolysis outcome using CT brain machine learning",Elseiver, Neuro Image Clinical, vol. 4, pp. 635-640, 2014.

[27]Darya Chyzhyk, Rosalía Dacosta-Aguayo, Maria Mataró, Manuel Graña, "An active learning approach for stroke lesion segmentation on multimodal MRI data", Neuro computing, vol.150(2015), pp. 26–36, 2015.

[28]BabakGhafaryasl, Fedde van der Lijn, Mari¨ellePoels, Henri Vrooman, Mohammad ArfanIkramWiro J. Niessen, Aad van der Lugt, MeikeVernooijandMarleen de Bruijne, "A computer aided detection system for cerebral microbleeds in brain MRI. IEEE, ISBI 2012, pp. 138-141, 2012.

[29]Jeena R S, Dr.Sukesh Kumar. A,"Comparative Analysis of MRI and CT Brain Images for Stroke Diagnosis",IEEE (ICMiCR-2013), pp. 1-5, 2013.

[30]R.Karthik, R.Menaka, "A comprehensive framework for

classification of brain tumour images using SVM and curvelet transform", Int. J. Biomedical Engineering and Technology, vol. 17, no. 2, pp. 168-177, 2015.

[31]Nirmalya Ghosh, Yu Sun, Bir Bhanu, Stephen Ashwal, Andre Obenaus, "Automated detection of brain abnormalities in neonatal hypoxia ischemic injury from MR images", Elseiver, Medical image analysis, vol. 18, no. 7, pp.1059-1069, 2014.

[32]Nooshin Nabizadeh, Nigel John, Clinton Wright, "Histogram-based gravitational optimization algorithm on single MR modality for automatic brain lesion detection and segmentation",Elseiver, Expert Systems with Applications, vol. 41, no. 17, pp. 7820–7836, 2014.

[33]MasamichiIkawa, Makoto Yoneda, Tomoko Muramatsu, Akiko Matsunaga, Tetsuya Tsujikawa,Tatsuya Yamamoto, Nobuyuki Kosaka, Kazuyuki Kinoshita, Osamu Yamamura, Tadanori Hamano,YasunariNakamoto, HirohikoKimur , "Detection of preclinically latent hyperperfusion due to stroke-likeepisodes by arterial spin-labeling perfusion MRI in MELAS patients", Elseiver, Mitochondrion, vol. 13, no.6, pp. 676–680, 2013.

[34]Shan Shen, Andr´e J. Szameitat, and Annette Sterr , "Detection of Infarct Lesions From Single MRI Modality Using Inconsistency Between Voxel Intensity and Spatial Location—A 3-D Automatic Approach",IEEE Transactions On Information Technology In Biomedicine, vol. 12, no. 4, pp. 532-540, 2008.

[35]April Khademi, Anastasios Venetsanopoulos and Alan R. Moody, "Robust White Matter Lesion Segmentation in FLAIR MRI",IEEE Transactions On Biomedical Engineering, vol. 59, no. 3, pp. 860-871, 2012.

[36]Y.Kabir, M.Dojat, B.Scherrer, F.Forbes, C.Garbay, "Multimodal MRI segmentation of ischemic stroke lesions". IEEE August 23-26, 2007, pp.1595-1598, 2007.

[37]Menaka R, Rohini S, "Efficient Detection of Ischemic Stroke from MRI images using Wavelet Transform", International Journal of computer science and information technology Research, vol. 2, no. 3, pp. 446-454, 2014.

[38]R.Menaka, Karthik.R, Shivangi Gupta and Archit Mishra , "Ischemic Stroke Detection from MRI Diffusion images using bifurcation analysis of texture features and fuzzy based segmentation",International Journal of Tomography and Simulation, vol. 28, no. 2, pp. 117-125, 2015.

[39]NooshinNabizadeh, MiroslavKubat, "Brain tumors detection and segmentation in MR images: Gabor wavelet vs. statistical features. Elseiver, Computers and Electrical Engineering 2015, pp.1-16, 2015

[40]P.Shanthakumar, P.Ganeshkumar, "Performance analysis of classifier for brain tumor detection and diagnosis", Elsevier, Computers and electrical Engineering, pp. 1-10, 2015.

[41]El-Sayed A. El-Dahshan, Heba M. Mohsen, Kenneth Revett, Abdel-Badeeh M. Salem, "Computer-aided diagnosis of human brain tumor through MRI: A survey and a new algorithm". Elsevier, Expert system with application, vol. 41, no. 11, pp. 5526-5545, 2014.

[42]P.Dvorák, K.Bartušek, W. G.Kropatsch and Z. Smékal, "Automated Multi-Contrast Brain Pathological Area Extraction from 2D MR Images", Journal of Applied Research and Technology, vol. 13, pp. 58-69. 2015.

[43]Robert K.Kosior, BSc; M.Louis Lauzon, PhD; Nikolai Steffenhagen, MD; Jayme C. Kosior, PhD; Andrew Demchuk, MD, PhD; Richard Frayne, PhD, "Atlas-Based Topographical Scoring for Magnetic Resonance Imaging of Acute Stroke. A Journal of Cerebral Circulation, *Stroke*, vol. 41, pp. 3, pp. 455-460, 2010.