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Non-invasive grading and prognosis of Brain Tumours using fuzzy inferencing for rural India

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Abstract

A Brain tumour is an abnormal tissue that grows by uncontrolled cell division. CT and MRI scans are the two most important and commonly used imaging modalities to identify the presence of a brain tumour. The severity of the tumour is graded and prognosis can be predicted only after a biopsy procedure. We have developed a Non-invasive grading and prognosis prediction methodology using CT and MRI images that obviates the need of biopsy to confirm the presence of tumour and thereby helps the clinician in accurate diagnosis.

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1. Introduction

Brain tumours are named after the cell type from which they grow. They may be primary (starting in the brain) or secondary (spreading to the brain from another area). Treatment options vary depending on the tumour type, size and location; whether the tumour has spread; and the age and medical health of the person [13]. Treatment options may be curative or focus on relieving

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symptoms. Of the more than 120 types of brain tumours known, many can be successfully treated if diagnosed accurately and graded [20].

The treatment of Brain Tumour starts with the doctor obtaining the personal and family medical history and performing a complete physical examination. In addition to checking general health, the doctor performs a neurological examination to check mental status and memory, cranial nerve function (sight, hearing, smell, tongue and facial movement), muscle strength, coordination, reflexes, and response to pain [16,17]. An imaging scan is the first step to identify a brain tumour if present, and the place where it is growing. An imaging scan creates computerized images of the brain and spinal cord by examining it from different angles. Some scans use a contrast agent (or a dye) to allow the doctor to see the difference between normal and abnormal tissue. A patient may need more than one type of scan to diagnose a tumour, depending on its type and location. CT and MRI scans represent the two most important and commonly used imaging modalities [22, 26, 27, 28].

We have developed a unique methodology to determine the severity of the tumour from CT images [1,2]. The proposed detection and grading methodology will be of immense helpful to the rural population of India, since the cost of CT scan is less compared to a MRI scan. Moreover, MRI is not available in all rural centres, but on contrast CT is available in all rural centres [3, 19]. Hence the lay public prefer the low cost affordable CT scan as a tool to identify the presence of tumour using the proposed system and confirm the diagnosis using MRI.

The proposed methodology for brain tumour grading follows the procedural steps listed below,

- Symptoms based possibility of Brain tumour occurrence using Questionnaire.
- Screening using CT for suspected individuals.
- Evaluation of Tumour severity and Prognosis from CT images using Fuzzy Expert Tumor Grading System (FETGS).
- Screening using MRI considering the severity of the tumour based on FETGS results.
- Using MRI images to grade equivocal cases

2. Materials and Methods

The average number of patients referred to the Neurology department of SMVMC hospital, Pondicherry, India was approximately Nine Hundred. The Neurologist chose One Hundred patients, from that OPD list, whose symptoms were highly suspicious of intracranial tumour. These One hundred patients were chosen for the study. They were given a questionnaire to answer uniquely prepared for this research. The questionnaire contained a list of neurological symptoms, their duration and personal data like age, occupation, etc. All the one hundred patients answered the questionnaire. Thirty-five patients, who had symptoms highly indicative of brain tumour, were chosen for CT scan. The chosen patients were imaged using a 16 slice Philips CT scanner. Iodinated Contrast agents were used for imaging**.**

3. Brain Tumor Imaging Reporting and Documentation System

A BIRADS approach for Brain Tumours has been proposed. The BIRADS acronym stands for Breast Imaging-Reporting and Data System which is a widely accepted risk assessment and quality assurance tool in mammography [25], ultrasound or MRI. Similar to BIRADS a standard tool for Brain Tumour assessment, namely Brain Imaging Reporting and Data System (BrIRADS) was proposed. These are standardized numerical codes typically to be assigned by a radiologist after interpreting a CT using the FETGS system has been developed. This allows for concise and unambiguous understanding of patient records between multiple doctors and medical facilities. BIRADS approach to Brain Tumors is given in Table 1

Table 1 BIRADS approach to Brain Tumors

Br-IRADS No	Assessment
1	Normal Study, No Abnormal Finding on Scan Date (using CT)
2	Benign Finding
3	Border-Line Findings require further study, Appropriate Action
4	Highly Suspicious of Malignancy - Confirmatory Test Required (using MRI)
5	Known Biopsy - Proven Malignancy

3.1 Questionnaire for Initial Screening

The questionnaire to identify individuals for ascertaining possibility of Brain tumours based on Symptoms has been prepared exclusively for this research study with the help of a Neurologist. The Questionnaire consists of two stages. They are as follows; Preliminary or Primary and Secondary stage. In the Preliminary stage, symptoms of tumour were identified, based on the individual's age, family history and specific personal traits. In the Secondary stage, the detailed information about the symptoms were evaluated

3.2 Fuzzy Expert Tumour Grading System

A Fuzzy Expert grading system was designed [1] for predicting the severity of the brain tumours from CT images. For each patient two images were considered for the study. One image was the Plain CT image and the other was the contrast enhanced CT image. The images were converted into grayscale and tumour region was segmented using Region Growing method [4,5,6, 21]. The results of image segmentation are given in Fig 1. From the segmented image size of the tumour, shape of tumour [8,9,10], Plain image intensity and contrast image intensity parameters were extracted. Fuzzy inferencing mechanism was used to grade the tumour and predict the prognosis rate. Tumour grading is a key factor, influencing the choice of therapies, particularly determining the use of surgery, adjuvant radiation, chemotherapy and prognosis [20].

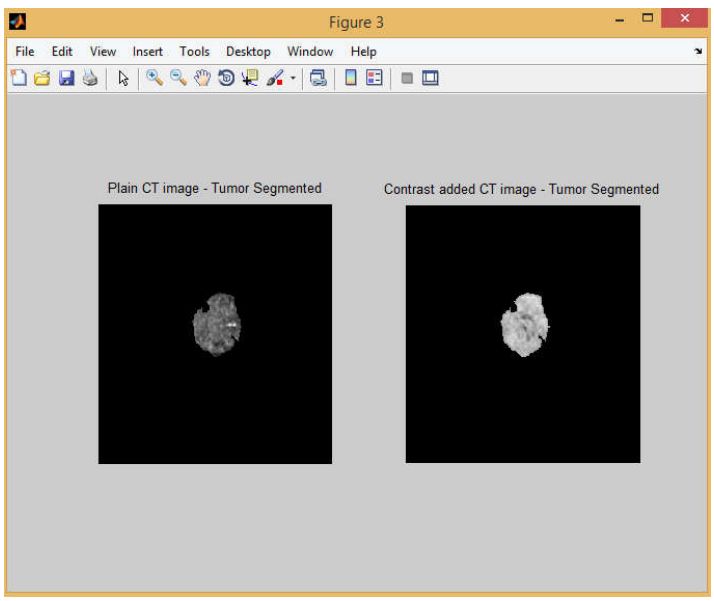

Fig 1 Segmented Image

The results of FETGS were tabulated in Table 2

Table 2 FETGS output with physical meaning for grading and prognosis

Input range		**Fuzzy Output**		**Crisp Output**	
Grading (%)	**Prognosis (%)**	**Grading (%)**	**Prognosis (%)**	**Grading**	**Prognosis**
0 – 35	60 – 100	17.7	85.2	Benign	Good
25 – 75	20 – 70	50.5	44.9	Borderline	Poor
70 – 100	0 – 30	87.8	14.8	Malignant	Very Poor

Table 2 shows the ability of FETGS to provide the right decision for the doctor on the malignancy and prognosis. The values listed

above indicate the percentage degree of malignancy in accordance with the data collected. Expert opinion [3] indicates the normal percentage chances of getting malignancy were above 60 - 100% under the given conditions, whereas the FETGS was able to the right decision as, 87.8% chances of malignancy.

4. Validation of FETGS

The validation of FETGS was done by comparing the results given by the doctor and the results obtained from FETGS system. Hence three sets of images were employed for validating the performance of FETGS. Set A contains 35 images that were initially collected from SMVMC hospital for designing the FETGS.

4.1 SET A

The images in SET A were obtained from the hospital along with doctors' reports. A mixture of malignant and benign cases was obtained. The results of the FETGS with SET A are given in Table 3. The main classification in the system, was identified either as Benign or Malignant. When the result of FETGS was borderline, MRI results were used for further categorization as Benign or Malignant based on the tumour

Table 3 Comparison of Grading Results of FETGS with Doctors Report (SETA)

Tumour Types	FETGS	Doctors Report
Malignant	14	15
Benign	15	15
Borderline	6	5
Total	35	35

4.2 SET B

SET B consists of 35 new set of proven case images obtained from Indira Gandhi Govt. General (IGGG) hospital. The images in SET B were obtained from the hospital without doctor's reports. The images were fed to the FETGS and the results were obtained and printed. Reports were obtained from the doctor later (A few days after). Doctors Reports were compared with FETGS results.

The results of the FETGS with SET B are given in Table 4

Table 4 Comparison of Grading Results of FETGS with Doctors Report (SETB)

Tumour Types	FETGS	Doctors Report
Malignant	13	16
Benign	10	12
Borderline	12	7
Total	35	35

In Table 4 malignant (13 out of 16) and benign (10 out of 12) tumours were graded correctly using the FETGS. In Borderline case, as per doctors' report there were only 7 cases but FETGS system has reported as 12. Since 3 cases of malignant and 2 cases of benign was reported as borderline by the system.

4.3 SET C

Set C consists of 50 new Images were collected from Internet Cancer Imaging Archive (http:\\public.cancerimagingarchive.net) for testing the system. The images in SET C were obtained from Internet along with doctor reports. A mixture of malignant and benign cases was obtained. The results of the FETGS with SET C are given in Table 5.

Table 5 Comparison of Grading Results of FETGS with Doctors Report (SET C)

Tumour Types	FETGS	Doctors Report
Malignant	21	25
Benign	13	15
Borderline	16	10
Total	50	50

In Table 5 malignant (21 out of 25) and benign (13 out of 15) tumours were graded correctly using the FETGS. In Borderline case, as per the doctor's report there were only 10 cases but FETGS system has reported as 16. Since 4 cases of malignant and 2 cases of benign was reported as borderline by the system.

4.4 Statistical parameters

Three parameters given in the Literature [6,12] were taken into consideration for statistical evaluation of the performance of the FETGS system. They are Sensitivity, Specificity and Accuracy.

- **Sensitivity** (also called the **true positive rate**, or the **recall** in some fields) measures the proportion of positives that are correctly identified.
- **Specificity** relates to the ability to correctly detect patients without a tumour. Specificity of a test is the proportion of healthy patients known not to have the disease
- **Accuracy:** A test method is said to be accurate when it measures what it is supposed to measure. This means it is able to measure the true amount or concentration of a substance in a sample.

In order to measure these statistical measures quantitatively, the following Terms have been defined.

- True positive (TP): Malignant Tumour correctly diagnosed as Malignant
- False positive (FN): Benign Tumour incorrectly identified as Malignant
- True negative (TN): Benign Tumour correctly identified as Benign
- False negative (FN): Malignant Tumour incorrectly identified as Benign

The sensitivity and accuracy of the FETGS in detecting Malignant, Benign and borderline are graphically represented in Charts 1 & 2 respectively.

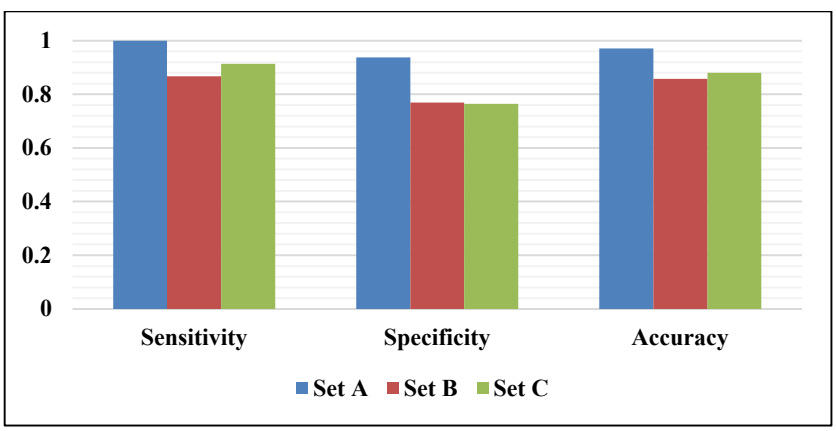

Chart 1 Performance Measures of FETGS

Chart 1 shows FETGS proposed method as 92.6% sensitive and 82.38% specific with all image sets in case of malignant and Benign. This shows the proposed technique is highly sensitive and equally specific for Malignant and Benign classification of Brain tumours. A high sensitivity is clearly important where the test is used to identify a serious but treatable disease.

The accuracy with SET A was the highest due to the fact that images in SET A were utilized in building the expert knowledge base for FETGS. For images from SET B, Overall Accuracy is 85.7%. This indicates the system has to be fine-tuned by correcting the rule based or the system can be made adaptive in nature. For images in SET C, Overall Accuracy is 88%. The change is mainly due to images collected from the internet. But the variation is less. Hence FETGS system was able to grade the tumour and predict the prognosis with an accuracy of 85.7%.

It was found that in all the cases, malignant and benign tumours were graded as Borderline by FETGS system. For further studies we have considered only SET B images. To improve the efficiency of the grading, borderline graded images of SET B are further screened using MRI. The screened images were segmented; tumour was detected and graded using FETGS. CT graded MRI images were referred as CM-FETGS. The results are tabulated below in Table 6

Table 6 Comparison of Grading Results of CM-FETGS with Doctors Report (SET B)

Tumour Types	CM-FETGS	Doctors Report
Malignant	14	16
Benign	12	12
Borderline	9	7
Total	35	35

In Table 6 malignant (14 out of 16) and benign (12 out of 12) tumours were graded correctly using the CM-FETGS. In Borderline case, as per doctors report we have only 7 cases but our system has reported as 9. Since 2 cases of malignant was reported as borderline by the system. Hence comparing Tables 4 and 6, the overall detection rate has improved by using MRI as second stage of grading for equivocal cases. The comparison of FETGS and CM-FETGS can be visualized from Chart 2.

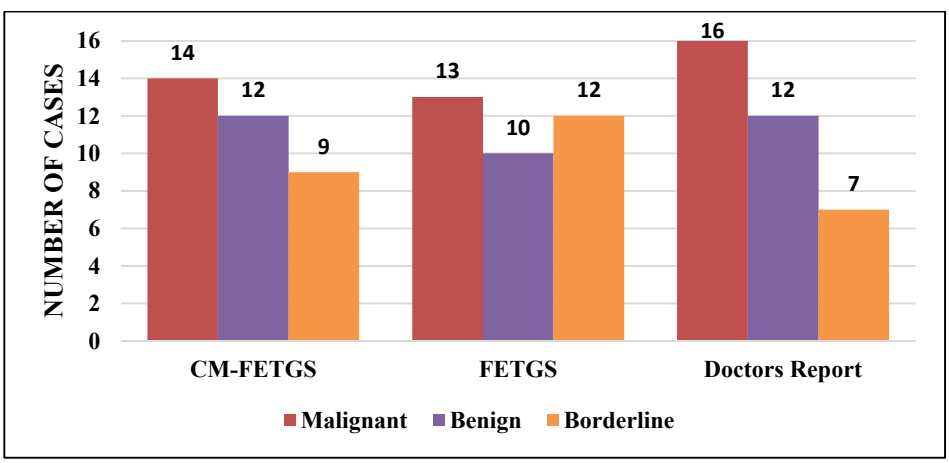

Chart 2 Comparison of FETGS and CM-FETGS

The improvement in performance measures is given in the Chart 3. Chart 3 shows that MRI can be used as a confirmatory tool for diagnosis of equivocal cases. The CM-FETGS has improved Sensitivity, Specificity and Accuracy compared to FETGS. This indicates the efficiency of the proposed method in detecting and grading brain tumours.

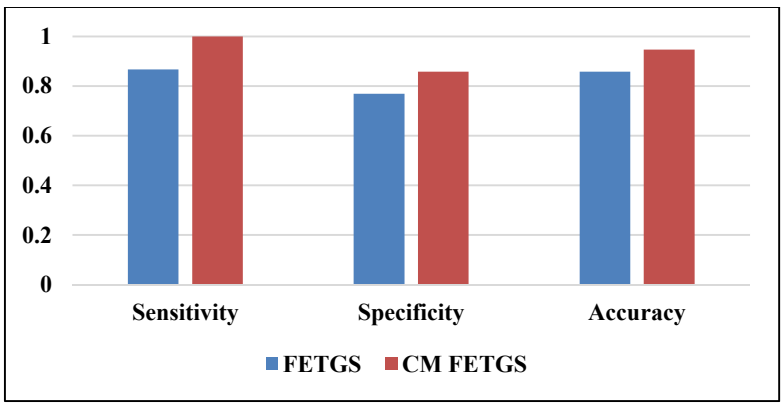

Chart 3 Performance improvement of CM-FETGS over FETGS

5. CONCLUSION

Hence proposed FETGS detection and BrIRADS grading methodology will be immense helpful to the rural population of India, since the cost of CT scan is less compared to a MRI scan. CT scan is easily available in all districts. Further it is easy to interpret, takes less time for imaging and relatively less costly. Therefore, it is chosen as the initial diagnostic mode for diagnosis and grading of brain tumours. CT has fewer disadvantages in that many bone artifacts are seen that reduce the image quality. Further multiplanar images have to be reconstructed from original axial images.

MRI scans gives exquisite anatomical details in intrinsically projected multiplanar images. Further there are no bony artifacts. Thus any tumour with equivocal CT findings can be clarified. Further in a given case of brain tumour the MRI scan gives more information than CT scan that help the doctor arrive at the accurate diagnosis and well plan appropriate treatment. The findings of brain tumours in CM-FETGS are very much diagnostic and hence most of the times obviate the need for invasive biopsy to be resorted for diagnosis and grading of tumours.

References

[1] Hemakumar, B., Dr. Malathi, R. and Dr. Anandanatarajan, R, "A FUZZY EXPERT SYSTEM (FES) DESIGN FOR GRADING OF BRAIN TUMORS IN CT IMAGES", International Journal of Biological and Biomedical Sciences, Vol. 3, No. 7, pp. 055-058, July, 2015.

[2] Hemakumar, B., Dr. Malathi, R. and Dr. Anandanatarajan, R, "Investigations of Different Segmentation Techniques for Characterizing Brain Tumors Based On Typical Shapes", International Journal of Research in Electrical and Electronic Engineering, Vol. 4, No. 6, (ISSN: 2320-1312) pp. 004-009, June 2015

[3] Christopher P. Hess, “Exploring the Brain: Is CT or MRI Better for Brain Imaging?” UCSF Department of Radiology & Biomedical Imaging, Review Article, 2015

[4] Mohammed Y. Kamil, “Brain Tumor Area Calculation in CT-scan image using Morphological Operations”, IOSR Journal of Computer Engineering, Volume 17, Issue 2, Ver. V (Mar – Apr. 2015), pp 125-128, 2015

[5] Swe Zin Oo and Aung Soe Khaing, "BRAIN TUMOR DETECTION AND SEGMENTATION USINGWATERSHED SEGMENTATION AND MORPHOLOGICAL OPERATION", International Journal of Research in Engineering and Technology, Volume: 03, Issue: 03, Mar-2014

[6] Deepthi Murthy, T.S,"Brain tumor segmentation using thresholding, morphological operations and extraction of features of tumor", IEEE International Conference on Advances in Electronics, Computers and Communications (ICAECC), 10-11 Oct. 2014, pp 1 -6

[7] Muhammed Anshad, P. et.al, “Recent methods for the detection of tumor using computer aided diagnosis — A review”, Proceedings of IEEE International Conference on Control, Instrumentation, Communication and Computational Technologies (ICCICCT), pp 1014 – 1019, 2014

[8] RoopaliR. Laddha, S.A.Ladhake, “A Review on Brain Tumor Detection Using Segmentation and Threshold Operations”, (IJCSIT) International Journal of Computer Science and Information Technologies, Vol. 5 (1), 607-611, 2014

[9] Myat Mon Kyaw, “Pre-Segmentation for the Computer Aided Diagnosis System”, International Journal of Computer Science & Information Technology (IJCSIT) Vol 5, No 1, February 2013

[10] Rania Hussien Al-Ashwal, Eko Supriyanto, Nur AnatiB Abdul Rani,et al; “Digital Processing for Computed Tomography Images: Brain Tumor Extraction and Histogram Analysis”, Mathematics and Computers in Contemporary Science, pp 119-128, 2013.

[11] Rajan Jain, MD, "Role of Imaging in Brain Tumors", CME, Medscape Education Radiology, 2013

[12] M.Karuna and Ankita Joshi, "AUTOMATIC DETECTION AND SEVERITY ANALYSIS OF BRAIN TUMORS USING GUI IN MATLAB", International Journal of Research in Engineering and Technology, pp 586-594, 2013

[13] Andrew H. Kaye & Edward R. Laws Jr,“ BRAIN TUMORS An Encyclopedic Approach", THIRD EDITION, Elseiver Publications, 2012.

[14] Roger Carpenter & Benjammin Reddy, “Neurophysiology A Conceptual Approach”, Hodder Arnold, An Imprint of Hodder Education, Fifth Edition, 2012

[15] Alejandro Veloz, et.al; “Brain Tumors: How Can Images and Segmentation Techniques Help”, InTech Publications Diagnostic Techniques and Surgical Management of Brain Tumors, pp 67 – 92, September, 2011

[16] AntoniosDrevelegas and Nickolas Papanikolaou, “Imaging Modalities in Brain Tumors”, Imaging of Brain Tumors with Histological Correlations, Springer Publications 2011

[17] Dr. Thomas M. Deserno, "Biomedical Image Processing", Series in Biological and Medical Physics, Biomedical Engineering, Springer Publications, 2011

[18] Kai Xiao et.al, “Brain MR image tumor segmentation with ventricular deformation “, IEEE International Conference on Intelligent Computer Communication and Processing (ICCP), 25-27 Aug 2011, pp 213 – 217

[19] Drevelegas & N. Papanikolaou, "Imaging Modalities in Brain Tumors", Imaging of Brain Tumors with Histological Correlations, Springer Publications, Chapter 2, pp 13 -33, 2011

[20] Understanding Brain Tumors, the Cancer Council NSW, December 2010

[21] Das A,” A Study on Prognosis of Brain Tumors Using Fuzzy Logic and Genetic Algorithm Based Techniques“, International Joint Conference on Bioinformatics, Systems Biology and Intelligent Computing, IJCBS '09, pp 348 - 351, 2009.

[22] Gonzalez, R. C. and Woods, R. E: “Digital Image Processing”, 3rd ed., Prentice Hall of India, 2009.

[23] Fei Peng, et.al., “Region Feature Extraction of Brain CT Image for Classification”, Proceedings of IEEE 2nd International Conference on Bioinformatics and Biomedical Engineering, pp 2495 – 2498, 2008

[24] S. Cha, "Update on Brain Tumor Imaging: From Anatomy to Physiology", American Journal of Neuroradiology, Issue 27, pp 475-487, March, 2006

[25] Margaret M. Eberl, et.al. “BI-RADS Classification for Management of Abnormal Mammogram", Journal of American Board of Family Medicine, Vol 19(2), pp:161-164, 2006.

[26] Q.Hu,G.Qian, A.Aziz, W.L.Nowinski, “Segmentation of brain from computed tomography head images,” Engineering in Medicine and Biology 27thAnnual Conference, pp 3375-3378, 2005.

[27] Greiner, G. et al, “Vision Modelling and Viualization – Proceedings”, Nov 20-22, 2002, Erlangen, Germany.

[28] James P. Earls, “Comparison Studies of CT and MRI in Patients with Hepatic Metastases”, Journal of Oncology, (Review Article) June 01, 2000