

Tissue Fate Prediction in Acute Stroke based on MRI

Benjamin Brandt
Computer Science Department
University of California, Los Angeles
Los Angeles, USA
benjibrandt@ucla.edu

Roy Lin
Computer Science Department
University of California, Los Angeles
Los Angeles, USA
rlin2k1@gmail.com

David Julius Macaraeg
Computer Science Department
University of California, Los Angeles
Los Angeles, USA
dmacaraeg@g.ucla.edu

Index Terms—*fluid attenuated inversion recovery, machine learning, magnetic resonance imaging, stroke, tissue fate prediction*

I. INTRODUCTION

STROKE kills about 140,000 Americans every year, meaning 1 out of every 20 deaths in the United States are stroke-related [1]. Put in a more startling way: someone in the United States has a stroke every 40 seconds, and, every 4 minutes, someone dies of stroke [1]. It is a serious, widespread issue, touching most people's lives. Prevention research and specific preemptive drug treatments are making great strides in lowering the risk of strokes, but the reality is that they still happen. Therefore, treatment of ischemic stroke patients is an absolute priority - particularly with a focus on maximizing the recovery of affected tissue. Integral to tissue recovery is the usage of tissue outcome prediction - the process of determining which stroke-affected areas may survive - to inform clinical decision-making. As such, given the common-place nature of strokes, and the importance of predicting its survivability, deducing better methods of prediction is absolutely imperative.

Conventional methods of obtaining images for the prediction of tissue outcome after the treatment of ischemic stroke patients include Computed Tomography (CT) Scan and Magnetic Resonance Imaging (MRI) Scan [5]. Both generally use techniques consisting of Cerebral Angiography or Source Perfusion Imaging [6]. Cerebral Angiography uses contrast material to produce detailed pictures of major blood vessels in the brain including blood clots or narrowing arteries [7]. The scans are timed perfectly with the arrival of the contrast into the brain [2]. Perfusion Imaging, on the other hand, use nonradioactive substances through the blood vessels and takes scans over time to see what areas of the brain got the most blood - giving information about blood flow throughout the brain [3]. Grey areas indicate occluded or clotted blood flow that comes with negative side effects and symptoms.

Three days after surgery to open up the blood vessel physically, another MRI Scan will be performed to see possible post-op damage. Fluid Attenuated Inversion Recovery (FLAIR) images are produced from this MRI Scan to annotate lesions post-surgery [5]. For this study, we will use Source Perfusion Weighted MRI scans obtained after the admission of the stroke patient and Machine Learning to predict possible Lesion growth after surgery. The main advantage of Machine Learning approaches to such images is that we can take advantage of a large number of previous surgeries and estimate future surgeries based on largely non-linear functions. These functions are obtained by methods including Linear Regression, Decision Trees, K-Nearest Neighbors, Logistic Regression, Support Vector Machines (SVMs), and Mixture Models.

Previously, we would rely on doctors analyzing contrast-intensity time curves which have a lot of noise and motion artifacts [8]. Manual analysis is time intensive and can be

unreliable. In current practice, programs use the spatial differences between diffusion and perfusion-weighted MRI to differentiate irreversible blockage of blood supply from salvageable tissue. Early models of tissue outcome based on computer vision and pattern recognition techniques have been trained on a voxel-by-voxel basis using perfusion imaging. However, more recently, relative to single-voxel-based methods, models of tissue prediction that use data in the surrounding area of the target have been shown an improved accuracy in relation to the predictive model. [10]

In Machine Learning, parameters are continually adjusted to achieve better performance with new training data. Past research studies on Hemorrhage Severity in the Brain have shown high accuracy using Machine Learning Models [9]. We will use Lesion labels and PWI - MRI Scans from past surgeries to predict Lesion labels for new surgeries.

Ultimately, the aim of this paper is singular: to examine the various machine learning methods of tissue outcome prediction, rank them, and determine which is the best. By best, we mean the method which has the highest rates of successful prediction, the most amount of the time; put shortly: the most consistently accurate. To achieve this goal, we utilize multiple machine learning algorithms available in the sci-kit learn package. First, we train them on sets of images such that they can observe before and after shots of brain tissue. Then, we allow them to operate on a broader set of images, this time predicting various tissue regions' survival via a binary survive or did not survive. We then compare the algorithms' predictions with the actual results of survival, and determine the accuracy. Clearly, more accurate is better, and so, in this way, we can deduce which algorithm is best suited to this problem domain. By creating such a ranking, we hope to create a reference for clinicians to use to better inform their decisions regarding tissue outcomes. Knowing the strengths and weaknesses of each machine-aided analysis, and their relative accuracy, will give decision-makers a greater context on which to base their understanding, and their ultimate choices. With clear-eyed, open data regarding various methods' effectiveness, clinicians will be able to more scientifically formulate plans of action, ultimately improving patient care and outcomes.

- [1] U.S. Centers for Disease Control and Prevention, "Stroke Statistics," U.S. Department of Health and Human Services. September 2017.
- [2] Jamary Oliveira Filho, PhD, "Neuroimaging of acute ischemic stroke", UpToDate, Inc., March 2018.
- [3] Johns Hopkins Medicine, "Brain Perfusion Scan," *Treatments, Tests and Therapies*. The Johns Hopkins University, The Johns Hopkins Hospital, and Johns Hopkins Health System.
- [4] Mayo Clinic, "Stroke," *Diseases and Conditions*. Mayo Foundation for Medical Education and Research.
- [5] Segawa F., Kishibayashi J., Kamada K., Sunohara N., Kinoshita M., "FLAIR images of brain diseases. Fourth Department of Internal Medicine, Toho University, Tokyo, Japan: U.S. National Library of Medicine. June 1994.

- [6] Akmal Sabarudin, Cantiriga Subramaniam, Zhonghua Sun, "Cerebral CT angiography and CT perfusion in acute stroke detection: a systematic review of diagnostic value," Diagnostic Imaging and Radiotherapy Programme, School of Diagnostic and Applied Health Sciences, Faculty of Health Sciences, Universiti Kebangsaan Malaysia, Kuala Lumpur, Malaysia; Discipline of Medical Imaging, Department of Imaging and Applied Physics, Curtin University, GPO Box U1987 Perth, Western Australia, Australia. August 2014.
- [7] Cedars-Sinai, "Cerebral Angiography", *Computed Tomography (CT) Scans*. Cedars-Sinai.
- [8] F. Giangregorio, A. Bertone, L. Fanigliulo, G. Comparato, G. Aragona, M.G. Marinone, G. Sbolli, P. Tansini, and F. Fornaria, "Predictive value of time-intensity curves obtained with contrast-enhanced ultrasonography (CEUS) in the follow-up of 30 patients with Crohn's disease," Gastroenterology Operative Unit, Hepatology and Digestive Endoscopy, Guglielmo da Saliceto Hospital, Piacenza, Italy. Operative Unit for Gastroenterology and Digestive Endoscopy, San Giovanni Vecchio Hospital, Turin, Italy. November 2009.
- [9] Yannan Yu, Danfeng Guo, Min Lou, David Liebeskind, Fabien Scalzo, "Prediction of Hemorrhagic Transformation Severity in Acute Stroke From Source Perfusion MRI," IEEE. December 2017.
- [10] Noah Stier, Nicholas Vincent, David Liebeskind, Fabien Scalzo, "Deep learning of tissue fate features in acute ischemic stroke," IEEE. November 2015.