

## Differentiation of brain stroke type by using microwave-based machine learning classification

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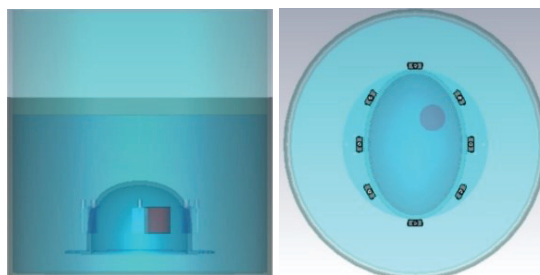
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Brain stroke is an emergency condition that is caused either by a blocked or a burst vessel (ischemic or hemorrhagic stroke, respectively), resulting into abnormal blood supply into the affected area, with severe and sometimes deadly consequences. Early diagnosis of the stroke is vital, as the time that passes from the offset of the symptoms is strictly correlated with the survival of the patient and the treatment success. Concurrently, it is also essential to successfully identify the type of the stroke as treating a hemorrhagic stroke (h-stroke) as an ischemic (i-stroke) stroke could be lethal for the patient [1]. Therefore, there is an increased need for a portable and low-cost diagnostic method that will detect and differentiate the type of the brain stroke as early as possible.

This paper investigates the potential of classifying the type of the stroke by using microwave-based signals, building upon work of other researchers, such as [2]. To evaluate the potential of this classification, we collected data produced by simulation models of our in-house prototype for brain stroke detection [3], using CST Microwave Studio®. Figure 1 shows the simulated prototype that is composed by a tank filled with 90% glycerol-water mixture. Within the tank we placed an ellipsoid brain phantom to which we assigned the dielectric properties of the average brain. The phantom is surrounded by 8 monopole antennas in an elliptical arrangement [3]. Then, we inserted a cylindrical target inside the brain phantom which mimics either the hemorrhagic or the ischemic stroke. The target is located in 3 different positions within the brain, one at the top right, one at the bottom left and one in the center of the brain phantom, respectively. Moreover, we varied the size of the stroke with a diameter ranging from 10 to 40 cm, with a step of 5 cm. Consequently, our database includes a total of 42 simulations. For each case, we measured the S-parameters for all antennas, totaling 2688 scattering recordings which will be used in our classification endeavors.

We will implement a cascade-classifier, in which we will first classify the location of the stroke ahead of its type: ischemic or hemorrhagic. Our rationale is that if we classify strokes that have been identified in the same location, we can better classify its type. We will compare two machine learning algorithms – decision trees and the K-Nearest Neighbors (KNNs) – with a k-fold cross validation methodology. With the proposed cascade-classifier we achieve better classification accuracies than 89.1% (KNN) and 84.5% (Decision Tree), which are the metrics obtained when classifying the accuracy type of stroke, when all locations are considered.



**Figure 1.** CST imaging prototype of the tank, the head phantom and the target for h-stroke at location 1

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