Evaluation of Hydrocephalic Ventricular in Brain Images using Fuzzy Logic and Computer Vision Methods

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Abstract. The purpose of this paper is classify cases of hydrocephalic ventricular of human brain images using fuzzy logic, based on the size of the ventricles of the human brain, using intelligent techniques combined with computer vision, the analysis of the ventricles size was based databases using magnetic resonance cases of normal ventricles, the criterion based of the fuzzy logic inference system and vision using the height, and volume of the ventricles to classify the hydrocephalic cases. The height, area and volume of the ventricles of the left and right brain were measured in 13 individuals, 10 normal and 3 cases of hydrocephalus. We expect that the symptoms of hydrocephalus using the proposed method are classified by the size of the ventricles with a significantly higher percentage when considering a large number of cases of hydrocephalus.

Keywords: Computer vision and image processing, bioinformatics and medical applications, fuzzy logic.

1 Introduction

The Hydrocephalus can be defined as a disturbance of the formation of flow, or absorption of cerebrospinal fluid (CSF) that leads to an increase in the volume occupied by the fluid in the central nervous system.

This condition could be termed as a disorder of CSF hydrodynamics. Acute hydrocephalus occurs in days, sub acute hydrocephalus occurs within weeks, and chronic hydrocephalus occurs over months or years. Conditions such as brain atrophy and focal destructive lesions also lead to an abnormal increase of cerebrospinal fluid in the central nervous system. In these cases, brain tissue loss leaves a void that is filled passively with CSF. These are not the result of a hydrodynamic disorder and therefore are not classified as hydrocephalus. A major misnomer used to describe these conditions was hydrocephalus ex vacuo.

This review focuses on the problems related to defining hydrocephalus and on the development of a consensus on the classification of this common problem. Such a consensus is needed so that diverse research efforts and plans of treatment can be understood in the same context. The literature was searched to determine the definition of hydrocephalus and to identify previously proposed classification schemes. The historic perspective, purpose, and result of these classifications are reviewed and analyzed. The concept of the hydrodynamics of cerebrospinal fluid (CSF) as a hydraulic circuit is presented to serve as a template for a contemporary classification scheme. Finally, a definition and classification that include all clinical causes and forms of hydrocephalus are suggested. The currently accepted classification of hydrocephalus into "communicating" and "no communicating" varieties is almost 90 years old and has not been modified despite major advances in neuroimaging, neurosciences, and treatment outcomes. Despite a thorough search of the literature using computerized search engines and bibliographies from review articles and book chapters, we identified only 6 previous attempts to define and classify different forms of hydrocephalus [1].

2 Motivation

In research, the needs of specialists impact area of medicine of Neuroradiology generates a motivation for this research project to develop image analysis methods of the brain using computer vision and intelligent systems, namely that all is not resolved in this field of neuroimaging, the idea is to develop an automated system that can serve as a support for medical specialists and thus to have a better diagnostic criteria based on the analysis of brain images.

2.1 Fuzzy Logic

Fuzzy logic is a form of many-valued logic; it deals with reasoning that is fixed or approximate rather than fixed and exact. In contrast with traditional logic theory, where binary sets have two-valued logic: true or false, fuzzy logic variables may have a truth value that ranges in degree between 0 and 1. Fuzzy logic has been extended to handle the concept of partial truth, where the truth value may range between completely true and completely false. Furthermore, when linguistic variables are used, these degrees may be managed by specific functions [2].

Fuzzy logic starts in 1965 proposal of fuzzy set theory by Lotfi Zadeh [3, 4]. Though fuzzy logic has been applied to many fields, from control theory to artificial intelligence, it still remains controversial among most statisticians, who prefer Bayesian logic, and some control engineers, that prefer traditional two-valued logic [5].

In this paper we use fuzzy logic to determine if the person has hydrocephalus or not, using two fuzzy systems that use height, area and volume of the left and right ventricles, which were obtained from a database of CT images Excel Medical Center.

3 The Ventricles of the Brain Metric Height, Area and Volume

We utilized a database of 13 individuals with 45 scans each for a total of 585 sample images to obtain the necessary metrics and to test the fuzzy inference system, 10 are normal people with hydrocephalus and 3 if then shown as obtained measures of height, area and volume of right and left ventricles [6].

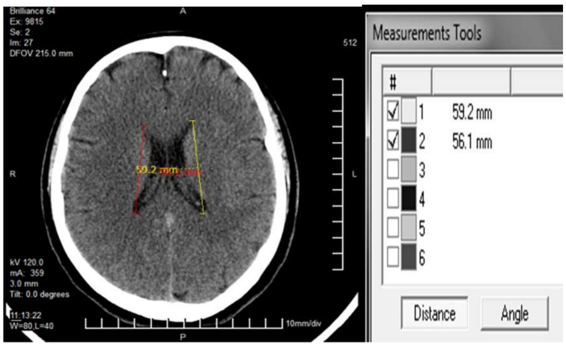

Fig. 1a) Computerized axial tomography, height of the ventricles, **1b)** Measurement Tools.

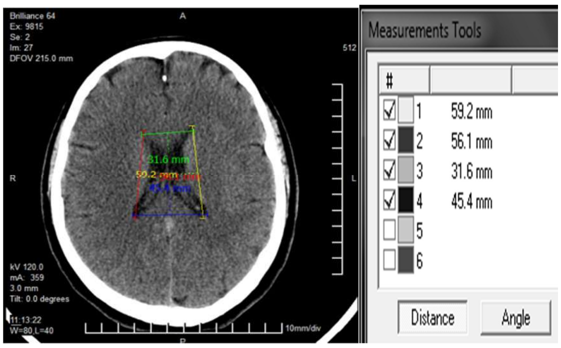

Fig. 2a) Computerized axial tomography, Area of the ventricles, **2b)** Measurement Tools.

It was used to support development of specialized software from Philips with which we read the CT images and look at different angles of the image. Figures 1a and 1b show an example of how to calculate the height of the right and left ventricles in the image by drawing a line that covers each Ventricle, measures are in units of millimeters, the height within the brain image of the left ventricle are shown in red and yellow ventricle right.

The height is obtained by drawing a straight line from end to end for each left and right ventricle, for example, in this case we have the height:
Right ventricle size: 59.2mm, Left ventricular measures: 56.1mm

The calculation of the area of the ventricles using the height of each ventricle and its base, forming a rectangle, take the base and the height and divide by two to calculate the area for each of the ventricles multiplying the base times height, it is in figures 2a) and 2b).

The following shows how to calculate the area of each ventricle for example:

Area = (base) x (Height
Right ventricle height 59.2mm and 38.5mm base of the right ventricle.
Area = (59.2mm) x (38.5mm) = 2279.2 mm^2

The following is an example of the calculation of the volume using the area and height of the ventricles:

Volume = (Area) x (Height)
Right ventricular volume: Area = 2279.2mm^2, Height = 59.2mm from the right ventricle to obtain the volume of the right ventricle. Volume = (2279.2mm^2) x (59.2mm), Volume = 134928.64 mm^3

The calculation of Left ventricular volume, area = 2159.85mm^2, height = 56.1mm, obtaining the right ventricular volume, Volume = (2159.85mm^2) x (56.1mm), Volume = 121167.58 mm^3

The following tables show the results of measurements of each of the test images which specify the measures normal and Hydrocephalus cases:

Table 1. Measurements (part 1).

Measures	Brain		Normal		Hydrocephalus	
Height(mm)	Ventricle	Right	50.7	68.0	70.0	90.0
		Left	48.9	72.1	73.0	90.0
Area(mm^2)	Ventricle	Right	870.94	1350.60	1270	2396
		Left	875.94	1355.57	1273	2386
Volume(mm^3)	Ventricle	Right	100	50	190	420
x million		Left	89	215	180	410

Table 2 shows measures of 10 normal individuals. VBH is the height of the ventricle of the brain, VBA is the area of the brain ventricle and VBV is the volume of the ventricle of the brain.

Table 2. Measurements (part 2).

Person		VBH		VBA		VBV	
		Right	**Left**	**Right**	**Left**	**Right**	**Left**
	1	60.0	54.8	1093.47	1093.47	131216.4	119844.312
	2	56.2	56.4	1187.93	1187.93	133760.918	133998.504
	3	66.2	70.9	1355.57	1355.57	179478.262	192220.676
	4	62.9	60.8	1237	1237	155614.6	150919.2
Normal	5	64.6	72.1	1467.81	1467.81	189641.859	211658.923
	6	50.7	51.9	875.94	875.94	88821.076	90923.35
	7	68.6	53.4	1242.87	1242.87	170522.45	132739.05
	8	50.7	48.9	991.02	991.02	100489.420	96921.756
	9	62.3	54.2	958.21	958.21	119393.277	103870.235
	10	66.3	65.3	1112.04	1112.04	147453.852	145229.812

Table 3 shows the measures of height, area and volume of the ventricles of the individual cases of hydrocephalus.

Table 3. Measurements (part 3).

Person		VBH		VBA		VBV	
		Right	Left	Right	Left	Right	Left
	1	75	73.7	1273.243	1273.243	190986.562	187676.091
Hydrocepha lus	2	86.5	84.6	2386.84	2386.84	412924.185	403854.174
	3	83.4	77	1888.71	1888.71	315036.828	290861.34

4 Evaluation of Fuzzy Inference System for Hydrocephalus

The proposed inference system uses three input variables, which are the height, area and volume of the ventricles, and one output variable, which is the staging evaluation hydrocephalus or normal membership functions are type triangular system is Mamdani type inference, the ranges established for the input variables and output based on the results tables 1, 2 and 3 is similar for right and left ventricle.

Figure 4 shows the inference system of evaluation cases of hydrocephalus to the right ventricle.

This fuzzy system is to the right ventricle of the brain has three input variables and output variable, and each input variable has three membership functions and the output variable has two membership functions. It is noted that the lowest height of the ventricles according to our tests was 48 mm and the highest was the 90 mm. as shown in Figure 5.

Figure 6 shows that the range area of the ventricles is a normal measure that would be 875.94 mm ^{2} and a case of hydrocephalus which would be 2386.84 mm$^{2.}$

Figure 7 shows that the lowest volume is 98 mm ^{3}and the highest volume was 420 mm^3 (it is necessary to multiply the range by one million).

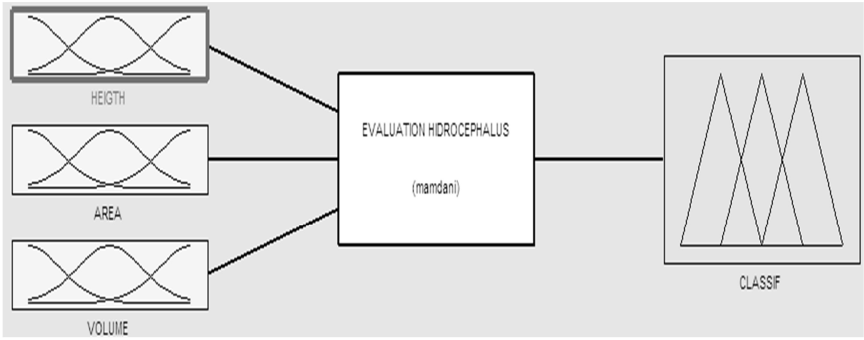

Fig. 4. Fuzzy system with three input variables and output.

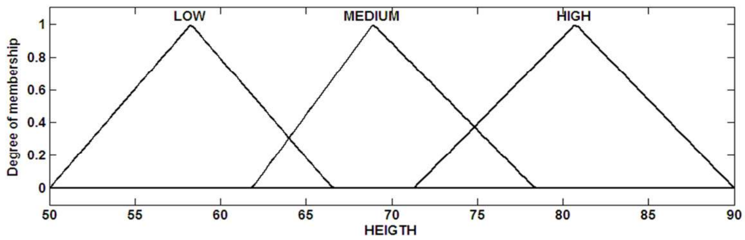

Fig. 5. Each variable has three membership functions are low, medium and high.

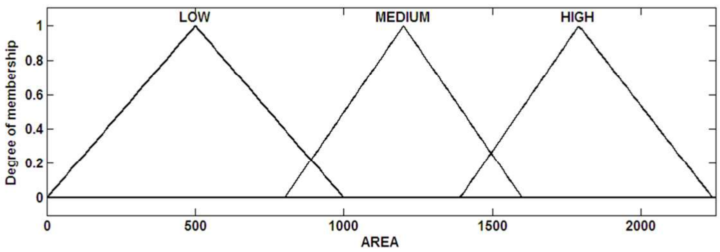

Fig. 6. Membership Functions of right ventricular Area.

Figure 8 shows the output of the fuzzy system that evaluates which cases of normal ventricles and those with a problem of hydrocephalus.

We can see that the output range consider the criterion of height. In the case of individuals who have longer ventricle of 90mm height are be considered cases of hydrocephalus, the criterion of the rules of fuzzy inference system considers its area and volume.

Figure 9 shows the rules of the two fuzzy systems as shown below, An example of the rules is if the ventricle is high, its area is high and the volume is high then classified as hydrocephalus

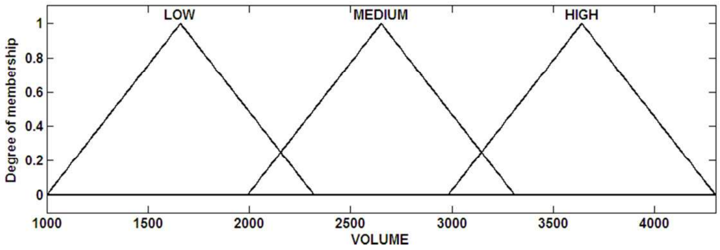

Fig. 7. Membership functions of right ventricular volume.

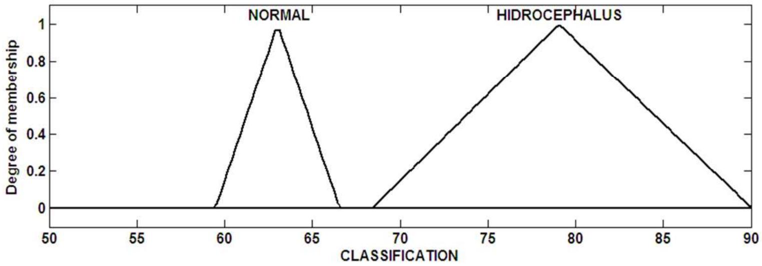

Fig. 8. Output membership functions to classify cases of hydrocephalus.

1. If (HEIGTH is LOW) and (AREA is LOW) and (VOLUME is LOW) then (CLASSIF is NORMAL)
2. If (HEIGTH is LOW) and (AREA is MEDIUM) and (VOLUME is LOW) then (CLASSIF is NORMAL)
3. If (HEIGTH is MEDIUM) and (AREA is HIGH) and (VOLUME is HIGH) then (CLASSIF is HIDRO)
4. If (HEIGTH is HIGH) and (AREA is HIGH) and (VOLUME is HIGH) then (CLASSIF is HIDRO)
5. If (HEIGTH is HIGH) and (AREA is MEDIUM) and (VOLUME is MEDIUM) then (CLASSIF is HIDRO)
6. If (HEIGTH is MEDIUM) and (AREA is MEDIUM) and (VOLUME is MEDIUM) then (CLASSIF is NORMAL)
7. If (HEIGTH is HIGH) and (AREA is HIGH) and (VOLUME is MEDIUM) then (CLASSIF is HIDRO)
8. If (HEIGTH is LOW) and (AREA is MEDIUM) and (VOLUME is MEDIUM) then (CLASSIF is NORMAL)
9. If (HEIGTH is MEDIUM) and (AREA is HIGH) and (VOLUME is MEDIUM) then (CLASSIF is HIDRO)
10. If (HEIGTH is MEDIUM) and (AREA is HIGH) and (VOLUME is HIGH) then (CLASSIF is HIDRO)

Fig. 9. The rules of the evaluation of fuzzy inference system.

5 Results and Conclusions

We utilized a database of 13 individuals with 45 scans each for a total of 585 sample images, To have a more diverse enough valid requires a larger database, and establishes contact with a neuroradiological center to get information, The results provide a criterion to classify cases of hydrocephalus based on the action of the ventricles height, area and volume, is one of the criteria that can be used to classify hydrocephalus and information required to relate the patient's clinical history. The tests were performed using a fuzzy inference system with a triangular membership function; it is necessary to experiment with other types of membership functions to see which provides better results and be able to use genetic algorithms for optimization of membership functions. Average measures were used the database, and statistical methods that allow us to validate the results.

We conclude that proposed method is a good approach, the proposed method is intended to be automated, and using methods of vision obtained measurements of the image and enter the evaluation system of fuzzy inference.

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