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Fuzzy Calculating of Human Brain's Weight Using Depth Sensors

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Abstract:

Despite of using Magnetic Resonance Imaging (MRI) data to calculating brain size in different genders and ages, using other methods could be so beneficial and low cost. Human brain's size has average weight of 1500 grams in adults , 350 grams in new born, 700 grams in 6-th month, 1050 grams in second year and 1260 grams in 6-th year; and any weight out of these ranges (with high variance) could be Microcephaly (brain does not develop properly) or Macrocephaly (head is abnormally large). These two phenomena appears in first few years of the child's age. A lot of factors could cause these sicknesses. It is better to detect it in first few years to proper decision be made. MRI system could do this with high expensive materials and effecting on human brain's by its magnetic field. This paper presents a fast and cheap method to do this experiment without any damage on the brain. Using Kinect V.2 sensor it is possible to handle this duty very well. System records depth data from brain in two different sides (front and side), and after matching images, probability of the sickness or disease could be detected with high accuracy. After converting 2.5 dimensional depth data to 3 Dimensional (3D), it is possible to calculate final brain's weight based on its 3D model's volume. System removes some of this volume due to skull and skin volumes. System is tasted on 10 normal and abnormal humans in different ages and genders and returned satisfactory and promising results. System returned 97.2% correct recognition accuracy in fuzzy recognition for three classes of Normal, Microcephaly and Macrocephaly. MRI systems return 100% correct recognition accuracy but according to capabilities of proposed system like being fast, cheap and ability to be used in real-time, it is worth to try it. So using chip depth sensors like Kinect could fasten the human brain's weight detection in real-time environment, but with lower accuracy versus MRI systems.

Keywords: *Magnetic Resonance Imaging (MRI), Brain size, Microcephaly, Macrocephaly, Kinect V.2 sensor, 3 Dimensional (3D), Fuzzy recognition*

I. Introduction

Using MRI (Magnetic Resonance Imaging) image [1] in Microcephaly and Macrocephaly detection [2] [3] is common in medical imaging. But this approach has its difficulties, which this paper tries to fix some of them. This section pays to fundamentals for starting the discussion and is the base of Section II, which is prior related works on related subject. Section III represents proposed depth detection method in details. Also sections IV and V include, results and conclusion respectively.

- *Importance of the research*

MRI system is good in accuracy, but this type of technique is dangerous for the brain, due to its magnetic field [1] and expensive, due to its tools and materials. In the other hand, this technique is so time consuming, which this paper tries to fix some of them. Using proposed technique or method, brain damage problem, time consuming problem and high cost problem could be fixed. Also system could be run in real time. But these advantages have disadvantage of 2±1 lower recognition accuracy which still worth to make such a system.

- *Microcephaly, Macrocephaly and detection methods*

Microcephaly is a medical condition in which the brain does not develop properly resulting in a smaller than normal head [4]. Microcephaly may be present at birth or it may develop in the first few years of life [4]. Often people with the disorder have an intellectual disability, poor motor function, poor speech, abnormal facial features, seizures, and dwarfism [4]. The disorder may stem from a wide variety of conditions that cause abnormal growth of the brain, or from syndromes associated with chromosomal abnormalities. A homozygous mutation in one of the microcephalin genes causes primary microcephaly [5] [6]. There is no known cure for microcephaly [4]. Treatment is symptomatic and supportive [4]. Also Zika virus [7] is one of the reasons to born these kids.

Macrocephaly is a condition in which the head is abnormally large; this includes the scalp, the cranial bone, and the contents of the cranium. Macrocephaly may be pathological, but many people with abnormally large heads or large skulls are healthy. Pathologic macrocephaly may be due to megalencephaly (enlarged brain), hydrocephalus (water on the brain), cranial hyperostosis (bone overgrowth), and other conditions. Pathologic macrocephaly is called "syndromic" when it is associated with any other noteworthy condition, and "nonsyndromic" otherwise. Pathologic macrocephaly can be caused by congenital anatomic abnormalities, genetic conditions, or by environmental events [8]. Macrocephaly is customarily diagnosed if head circumference is greater than two standard deviations (SDs) above the mean [9]. Also both of them could be detect using MRI (Magnetic Resonance Imaging) scan or sometimes, visually after birth. Also Macrocephaly has been seen in autistic children a lot [10].

Magnetic resonance imaging (MRI) is a medical imaging technique used in radiology to form pictures of the anatomy and the physiological processes of the body in both health and disease. MRI scanners use strong magnetic fields, magnetic field gradients, and radio waves to generate images of the organs in the body. MRI does not involve X-rays or the use of ionizing radiation, which distinguishes it from CT or CAT scans and PET scans [1]. Figure 1 represents two subject with Microcephaly and Macrocephaly condition and their related MRI images.

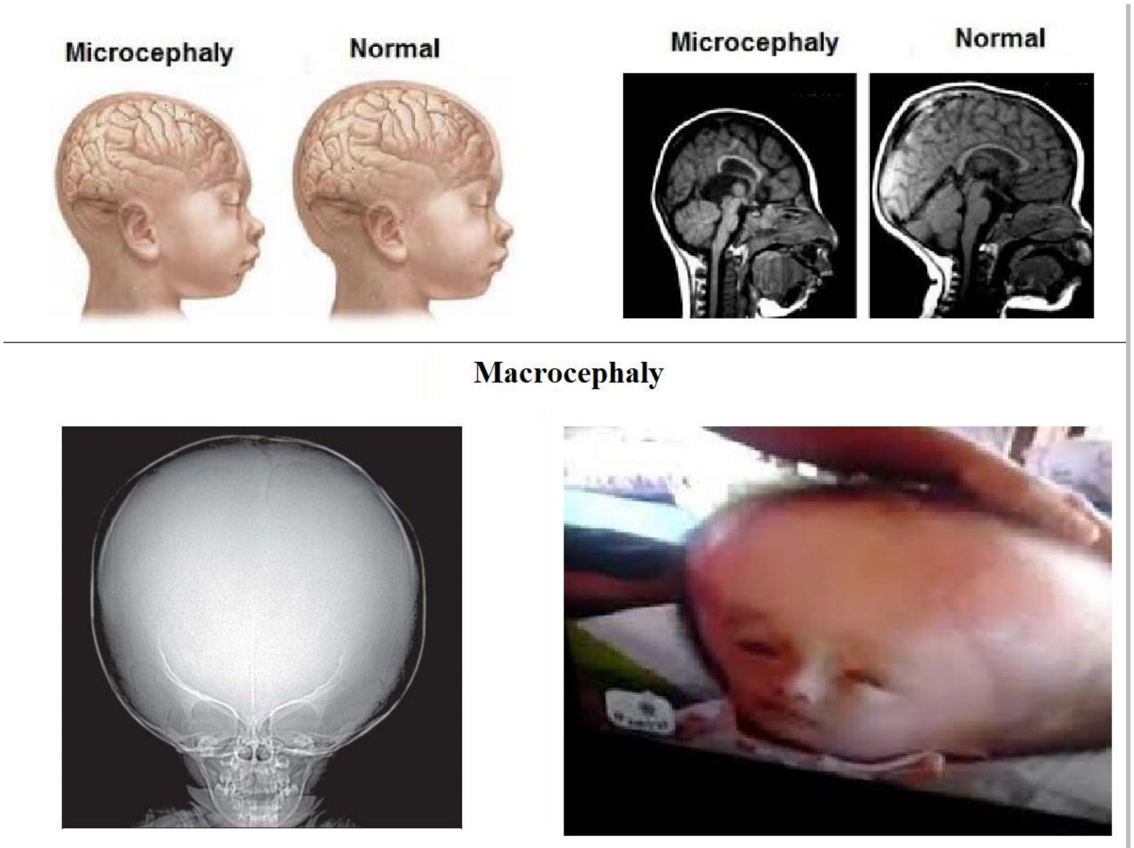


Figure 1. Two subject with and Macrocephaly condition and their related MRI images

- *Depth data and Microsoft Kinect V.2*

Depth or range images are some type of images, which are recorded using sensors enable to calculate distance between object and sensor [11] [12]. It means in depth image, each pixel is representative of distance in different units, depend on recording sensor. In Kinect this unit is in millimeter and in Kinect V.2 recording distance for depth image is in range of 0.8-5 meter. For example 1200 millimeter pixel value in Kinect depth image, means that part of object has 1.2 meter distance from the sensor. Kinect [13] is one of the Microsoft corporation products in 2014 and due to its price and accuracy, it is one of the most popular depth sensors in the world, especially among of researchers and developers. Figure 2 (a) shows one of the subjects in the experiment in both color and depth form before registration and making 3-D model, which is recorded using Kinect V.2, that is represented in Figure 2 (b) with its specification's. We employed two Kinect V.2 in this research.

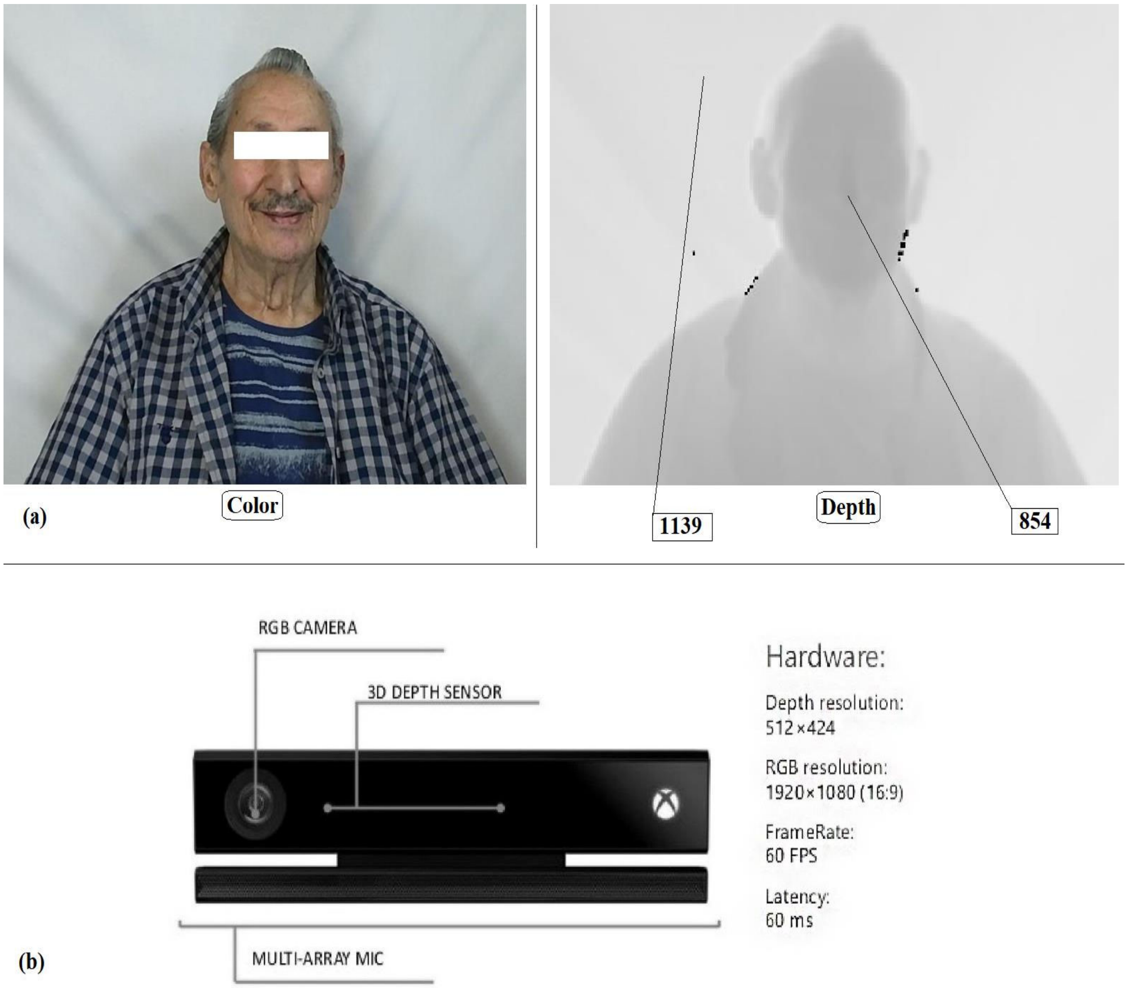


Figure 2. (a) One of the subjects in color and depth form, (b) Kinect V.2 specification

- *Depth data registration*

Image registration is the process of transforming different sets of data into one coordinate system. Data may be multiple photographs, data from different sensors, times, depths, or viewpoints [14]. It is used in computer vision, medical imaging [15]. military automatic target recognition, and compiling and analyzing images and data from satellites. Registration is necessary in order to be able to compare or integrate the data obtained from these different measurements. In this research two Kinect is used for registration and making final 3-D model. Figure 3 shows example of registration and making final 3-D model for (a), human body and (b), one of the subject's face. We used Non-rigid Registration [17] method in this research, which is one of the most applicable and famous one in the field of 3-D registration.

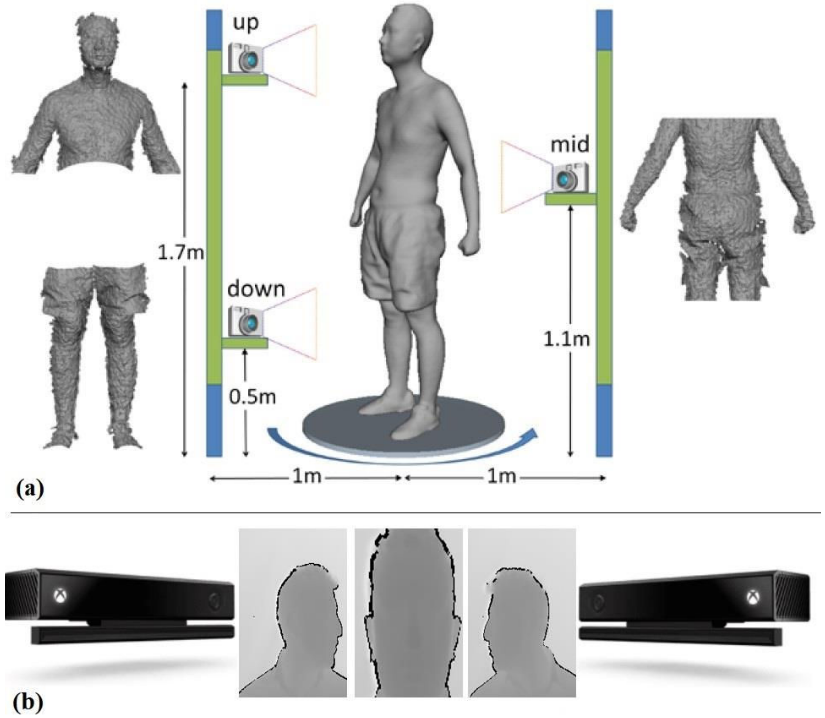


Figure 3. (a) Registration of human body using three Kinect sensors and making final 3-D model [16], (b) one of the subject's depth data from three view for registration and making final 3-D model

- *Fuzzy logic and sets*

Fuzzy logic is a form of many-valued logic in which the truth values of variables may be any real number between 0 and 1. It is employed to handle the concept of partial truth, where the truth value may range between completely true and completely false [18]. By contrast, in Boolean logic, the truth values of variables may only be the integer values 0 or 1. The term fuzzy logic was introduced with the 1965 proposal of fuzzy set theory by Lotfi Zadeh [19] [20]. Fuzzy sets is used for final classification in the paper. Fuzzy sets are often defined as triangle or trapezoid-shaped curves, as each value will have a slope where the value is increasing, a peak where the value is equal to 1 (which can have a length of 0 or greater) and a slope where the value is decreasing. Figure 4 represents final fuzzy classification model.

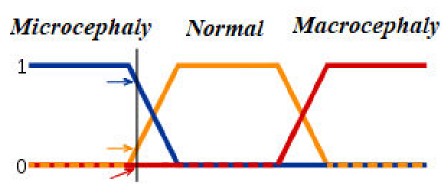


Figure 4. Fuzzy model of the final classification and its related Linguistic variables and sets

II. Prior works

Table 1 contains information about Microcephaly and Macrocephaly detection suing image processing techniques, mostly MRI images. Due to save some space and increasing the readability of the paper, prior related works are collected in one table in Table 1.

Table 1. Microcephaly and Macrocephaly detection, using image processing techniques by other researchers

Author (s)	Title	Subject	Year	Cite
Aragao, Maria de Fatima Vasco, et al.	Clinical features and neuroimaging (CT and MRI) findings in presumed Zika virus related congenital infection and microcephaly: retrospective case series study	Microcephaly and Zika Detection	2016	[21]
Guerrini, R., et al.	Neurological findings and seizure outcome in children with bilateral opercular macrogyric-like changes detected by MRI	Microcephaly Detection	1992	[22]
Garel, Catherine	The role of MRI in the evaluation of the fetal brain with an emphasis on biometry, gyration and parenchyma	Microcephaly Detection	2004	[23]
Mejdoubi, Mehdi, et al.	Brain MRI in infants after maternal Zika virus infection during pregnancy	Microcephaly and Zika Detection	2017	[24]
Priye, Aashish, et al.	A smartphone-based diagnostic platform for rapid detection of Zika, chikungunya, and dengue viruses	Microcephaly and Zika Detection	2017	[25]
Hazlett, Heather Cody, et al.	Magnetic resonance imaging and head circumference study of brain size in autism: birth through age 2 years	Macrocephaly Detection in Autism	2005	[26]
Piven, Joseph, et al.	Regional brain enlargement in autism: a magnetic resonance imaging study	Macrocephaly Detection in Autism	1996	[27]
Fombonne, Eric, et al.	Microcephaly and macrocephaly in autism	Microcephaly and Macrocephaly Detection in Autism	1999	[28]
Jarvis, Debbie, et al.	A systematic review and meta-analysis to determine the contribution of mr imaging to the diagnosis of foetal brain abnormalities In Utero	Macrocephaly Detection	2017	[29]
Hassanien, Omar A., et al.	Evaluation of the patency of endoscopic third ventriculostomy using phase contrast MRI-CSF flowmetry as diagnostic approach	Macrocephaly Detection	2018	[30]

III. Proposed method

Proposed Microcephaly and Macrocephaly detection system, stats off with data acquisition using Kinect or loading data from memory, which are recorded using two view of the subject's head. Having two view of depth data, demands registration process using non-rigid registration method for matching and joining data to make final 3-D model of the head. Depth data is called 2.5-D data which has great possibility to make 3-D model out of it. Now it is time to calculate the volume of the 3-D model which, this step need to be cleaned up a little bit, with decreasing 10 percent of the calculated volume as skin and skull. Normalizing the weight of the brain from calculated volume creates the next step as follow: Human brain's size has average weight of 1500 grams in adults, 350 grams in new born, 700 grams in 6-th month, 1050 grams in second year and 1260 grams in 6-th year, depending on the subject's age. Normally it happened in first few years of the child or in born time. Okay now it is time to fuzzification process for these weight ranges, and any weight out of these ranges (with high variance) could be Microcephaly (brain does not develop properly) or Macrocephaly (head is abnormally large). So we have three fuzzy classes of Microcephaly, Macrocephaly and normal. Final step is error calculation of actual value (subject's real condition) and predicted value (what we achieved using our method), as data or subjects are labeled or supervised, using MSE (Mean Squared Error) factor. Figure 5 represents our proposed method's flowchart. Also Figure 6 shows the same process, visually from the experiment.

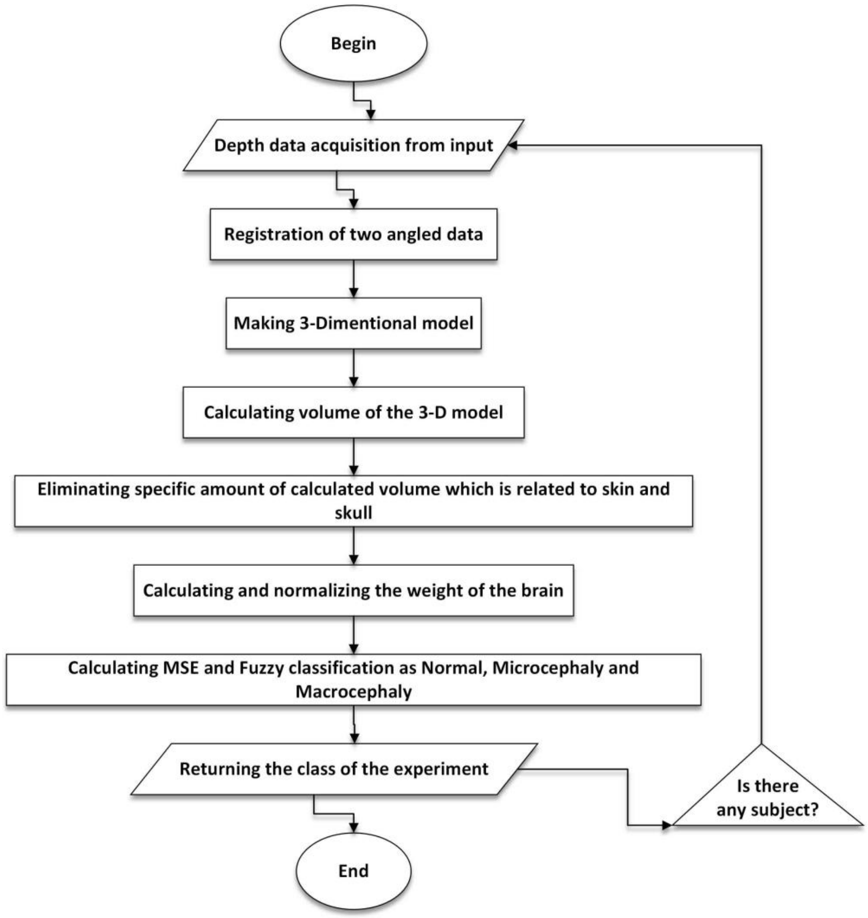


Figure 5. Proposed method's flowchart

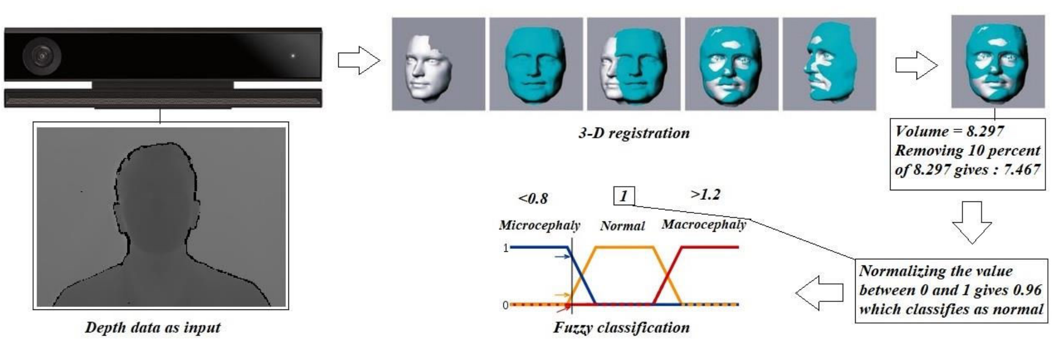


Figure 6. Process of the proposed method, visually

IV. Validation and results

This section demonstrate the whole experiment in details. Validations takes place on some normal and abnormal people and results will present as fuzzy classes (Microcephaly, Macrocephaly and normal). Also MSE factor, calculates error between actual value and estimated value for us.

- *Data*

System is tested using 10 subjects of normal and abnormal types. There were 6 normal and 4 abnormal subjects which abnormal subjects consists of 2 Microcephaly and 2 Macrocephaly in different ages and genders which Table 2 represents. Subject's frontal face in depth format is presented in Figure 7. Also depth data is recorded using Kinect V.2, as Figure 8 represents recording environment.

Table 2. Subjects' information

No	Age	Gender	Condition
1	7	Male	Normal
2	11	Female	Normal
3	12	Female	Normal
4	16	Female	Normal
5	27	Female	Normal
6	41	Male	Normal
7	7	Male	Microcephaly
8	6	Male	Microcephaly
9	8	Female	Macrocephaly
10	10	Male	Macrocephaly

Figure 7. Subject's frontal face in depth format

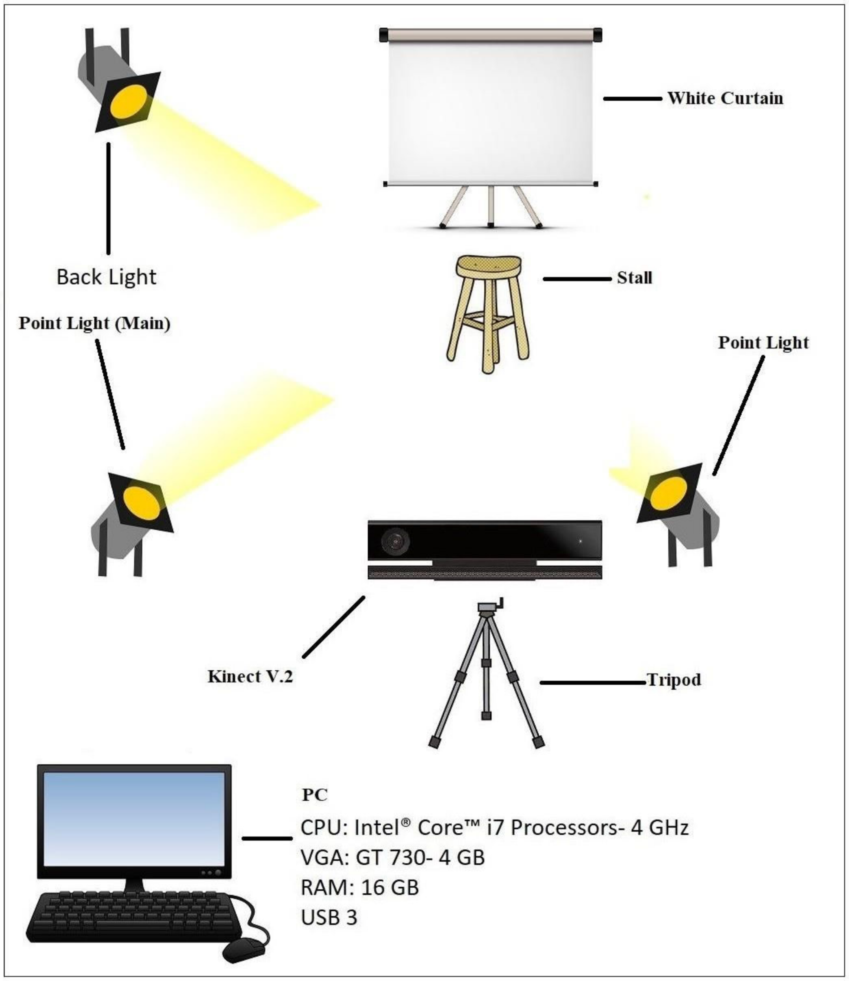


Figure 8. Experiment's environment

- *MSE*

Mean squared error (MSE): This is an estimator (for estimating an unobserved quantity) measures the average of the squares of the errors or deviations, which is, the difference between the estimator and what is estimated. The MSE is a measure of the quality of an estimator. It is always non-negative, and values closer to zero are better.

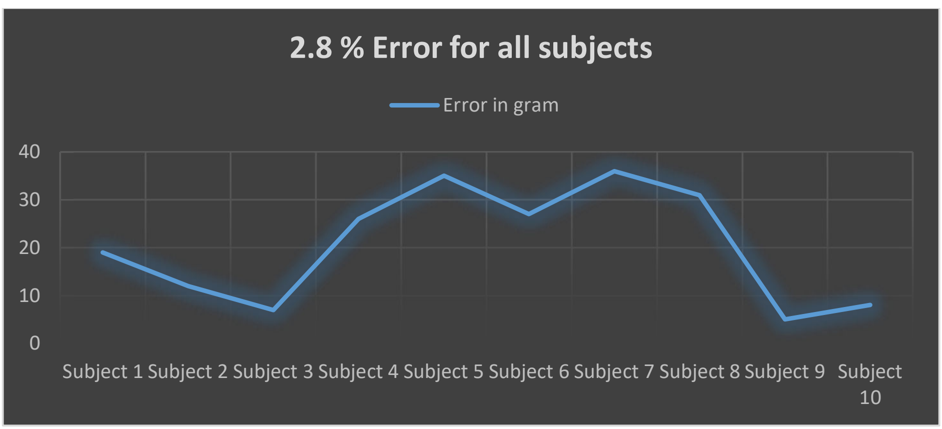
$$\mathrm{MSE} = \frac{1}{\mathrm{M} \times \mathrm{N}} \sum_{i=0}^{N-1} \sum_{j=0}^{M-1} [X(i,j) - Y(i,j)]^2 \qquad (1)$$

In which, X and Y are two arrays with the size of M*N. To any extent Y resembles X, the value of MSE will reduce. Table 3 shows MSE value for estimator or actual value (subject's real condition) and what is estimated or predicted value (what we achieved using our method), in relation to brain's weight. Also Figure 9 presents these values in graphical format.

Table 3. Validation results using MSE factor

Subject	Real Weight	Estimated Weight	Error
1	1301 gram	1320 gram	19 gram
2	1411 gram	1399 gram	12 gram
3	1398 gram	1391 gram	7 gram
4	1454 gram	1480 gram	26 gram
5	1532 gram	1497 gram	35 gram
6	1587 gram	1560 gram	27 gram
7	1025 gram	989 gram	36 gram
8	970 gram	1001 gram	31 gram
9	1550 gram	1555 gram	5 gram
10	1683 gram	1691 gram	8 gram
All	13911 gram	13883 gram	**2.8 % Error**

Figure 9. MSE error values in gram for each subject



V. Conclusion, discussion and suggestion

Using depth sensors could aid medical image processing, especially when 3-D model analysis of the subject is necessary. As using MRI imaging is so expensive and time consuming in calculating brain size, another method like depth sensors could be replaced. As proposed method shows, 2.8 error percentage on 10 subjects is a promising sign of new method's applicability. Using Kinect sensor instead of MRI system, could be so beneficial in calculating brain's weight and size, especially when time and cost has high of importance. To detect Microcephaly and Macrocephaly phenomenon, which detection could be done outside of the subject's head, using such a system is recommended. It is fast, portable, low cost and has no danger of magnetic field in it. It is suggested to make such a system as a real time system for achieving even better result.

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