Research & Analysis Journals

RA Journal of Applied Research
ISSN (e): 2394-6709
||Volume||3||Issue||12||Pages-1288-1294||December-2017||
Index Copernicus ICV: 74.25, DOI: 10.18535/rajar/v3i12.05

Bone Age Assessment with Fuzzy Logic

Aysun Coskun[1], Yasin Yılmaz[2]

[1]Department of Computer Engineering, Gazi University Faculty of Technology, Ankara, Turkey
[2]Department of Computer Education, Gazi University Instute of Information, Besevler, Ankara, Turkey

Abstract: Bone age estimated with left hand graphy takes an important place in follow up of child development. Assessment of bone age was aimed in the current study. Areas of carpal bones were calculated from reference graphics for related age groups. Inputs of fuzzy system were formed using calculated information. Bone age was estimated with fuzzy inference system. Users were provided to estimate bone age from graphics via prepared software. Hand graphics of healthy children were estimated in fuzzy system and results were evaluated. Accurate results were estimated in a ratio of 75,6% of 387 graphics analyzed with the prepared system. Fuzzy system designed using carpal bone areas would be able to be used in bone age automations prepared in the future.

Key words: fuzzy logic, fuzzy systems, bone age assessment, bone age

1. INTRODUCTION

Radiographic imaging studies done for evaluation of skeletal system maturity constitute a great deal of pediatric radiography demands. Determining whether a developmental problem is present or not is crucial for diagnosis of diseases. Bone age assessment is also essential for some endocrinologic diseases concerning thyroid, pituitary glands and gonads. Maturation of skeletal system may be evaluated radio logically in children who are very short or very tall compared to peers. Bone maturation and development may increase or decrease in many syndromes, alimentation disorders and bone dysplasia. Interpretations may be done according to bone age for correction of scoliosis, extremity length differences. Evaluation of bone maturation is a complex matter that may differ according to differences between observers and variations that is frequently seen in normal children [1].

2. FUZZY LOGIC

Fuzzy logic was first suggested by Lotfi A. Zadeh from California Berkeley University in 1965. Fuzzy logic refers to very valuable thoughts and applications including intermediate verifies instead of 0-1 in other words false-true evaluation. Main difference between fuzzy logic and math is that math only allows extreme values. Modeling and controlling complex systems with conventional mathematical methods are difficult because of this because data should be accurate. Fuzzy logic relieves the subject from this obligation and provides a more qualitative definition. Saying that one is middle aged instead of saying 38,5 years old is a sufficient data for many applications [2],[3].

Fuzzy logic brings membership degree conception to set theory and interprets the ratio of membership to the set. For example; it may be indicated with statements as ‘while a 70-year-old person is a member of oldies set in a ratio of 100%, a 30-year-old person is a member in a ratio of 35%.

RA Journal of Applied Research
ISSN (e): 2394-6709
||Volume||3||Issue||12||Pages-1270-1287||December-2017||
Index Copernicus ICV: 74.25, DOI: 10.18535/rajar/v3i12.04

Central concept of fuzziness theory is fuzzy sets. Limitations of the concept may vary individually. As definite limitations are not in question, the concept cannot be formulated easily also mathematically. A fuzzy set may be represented clearly with its membership function. Membership may take every value between 0 and 1. Making a fine adjustment between ‘’absolutely pertaining’’ or ‘’absolutely not pertaining’’ is possible with such a membership function [4].

3. FUZZY SYSTEMS

Using fuzzy logic as a way of solution of a mechanism constitutes the presence of fuzzy systems. Fuzzy systems are composed of input data, output data and fuzzy logic circuit. Fuzzy logic circuit converts input data to fussiness and takes into decision mechanism and thereafter converts to definite information via clarifier [5].

Membership functions of input data are determined in fuzzy systems. Fuzzy system would do calculations with rule sentences formed with membership functions. Fuzzy calculation would be converted to a linear number in the clarifier according to the status of chosen fuzzy modeling [6],[7].

4. METHODS OF BONE AGE ASSESSMENT IN CLINICS

‘’Bone age’’ also defined as ‘’skeletal age’’ estimated using hand-wrist graphics is an indicator of development in humans. It includes all growing period from birth to maturity. “Radiographic Atlas Of Skeletal Development of the Hand and Wrist” atlas known as Greulich-Pyle atlas and ‘’TW2’’ method known as Tanner-Whitehouse, evaluating left hand bones individually are used for bone age assessment in clinics. Mainly pediatricians, orthopedists, physics anthropologists and the ones interested in human development use this technique [8],[9],[10].

Greulich and Pyle, Tanner-Whitehouse (TW2) are the most commonly used techniques for bone age assessment at present. Both techniques are based on maturity markers despite their different theoretical approaches [11].

5. BONE AGE ASSESSMENT WITHFUZZY LOGIC

When bone age assessment studies were analyzed, it was concluded that bone age assessment could be done from carpal bone development of prepubertal children. When developmental differences between boys and girls were taken into consideration, it was considered that a solution could be reached from areas of carpal bones and a solution was developed [12],[13].

Reference images in ‘’Hand Bone Age’’ book accepted as the reference book for bone age assessments were used [8]. Carpal bone areas of reference graphics according to ages were calculated with the software prepared in mat lab program. As the result would be relative with area calculation, ratio calculation was preferred. Rating was done according to capitates bone that develops first and has the biggest surface area.

When carpal bone ratios are analyzed, it is seen that developing bones in 0,66 years (8 months), 1 years, 1.5 years, 2 years, 2,5 years are only capitates and hamates bones. There is only hamates/capitates ratio in this period. As the ratio in this period does not show a regular curve, another data is needed. When hand graphies are analyzed, proximity of capitates and hamates bones is observed to decrease gradually. This data seems to be able to be helpful for bone age assessment. An input data was also formed for fuzzy system by calculating ratio of distance between capitates and hamates bones to capitates bone area. This data will be used for estimations

Research & Analysis Journals
RA Journal of Applied Research
ISSN (e): 2394-6709
||Volume||3||Issue||12||Pages-1270-1287||December-2017||
Index Copernicus ICV: 74.25, DOI: 10.18535/rajar/v3i12.04

of 0.66 year, 1 year, 1.5 years, 2 years, 2.5 years estimations.

Designing Fuzzy System That Will Estimate Bone Age

Seven inputs and 1 output will be in fuzzy system. Membership functions were determined according to solution condition of each input data. Rule table of fuzzy system will be formed by determination of membership functions of output data and solution of the problem will be wanted. Fuzzy system was formed with ‘’Matlab’’. Parameters of membership functions were calculated according to calculated carpal bone areas and rule sentences were formed.

There are 12 rule sentences formed. These sentences are connected each other with membership functions of input data and give related membership function of output data as the result. Membership functions and rule sentences were formed for each age interval. Bone age will be estimated as the result of calculation of fuzzy system.

Determination of these inputs and data, forming rules and calculating the result as the result of clarifying were prepared in mat lab fuzzy logic inference system. Mamdani fuzzy modeling was chosen for fuzzy system. The system adjusted as 7 inputs and 1 output was prepared by taking and method minimum, or method maximum, implication minimum, aggregation maximum and clarifying method centroid.

6. BONE AGE ASSESSMENT PROGRAM WITH FUZZY LOGIC IN PRE-PUBERTAL (0-7 YEARS) CHILDREN

Interface (GUI) prepared in mat lab makes the following operations respectively:

- Loading the image
- Choosing the carpal bones as polygon
- Bone age assessment
- Indicting the data to the file that will be recorded

Assessment of program results

387 healthy human radiography is analyzed from database by program [15]. 14 out of 387 graphics analyzed were sifted because of reader errors. This condition arises from not understanding the computer program, not being able to master the subject and lack of attention. This is a good ratio for an assessment. Results of 373 graphics would be assessed.

When estimated values were evaluated, it was seen that fuzzy system was most successful in Caucasians. Successful detection ratio was 82% in Caucasians. Ratios were 75%, 65% and 64% in Hispanics, Africans and Asians respectively. The reason for this may be that reference images belong to Caucasians. Effect of ethnic origin on development has been observed once more. A distinct success is observed in Caucasians also with respect to the best ratio in terms of estimated values.

When estimated values were assessed in terms of gender, graphies of females were seen to give better results. Successful ratio that is 88% in females was only 64% in males. We can conclude that fuzzy system is more successful in females.

As success of estimated values according to age groups constitutes the basis of fuzzy system, it also reflects the success and shortcomings of fuzzy system. If 90% success was targeted in the designed fuzzy system, membership functions of areas fewer than 90% success should be reviewed again. Improvement would be required in the whole system by taking the fact that changes in membership functions would affect the whole fuzzy system into consideration.

Successful ratio was estimated as 88% for 0 age group, 89% for 1 age group, 72% for 2 age group, 90% for 3 age group, 88% for 4 age group, 88% for 5 age group, 90% for 6 age group and 92% for

RA Journal of Applied Research
ISSN (e): 2394-6709
||Volume||3||Issue||12||Pages-1270-1287||December-2017||
Index Copernicus ICV: 74.25, DOI: 10.18535/rajar/v3i12.04

7 age group in females. As seen here, accuracy value of fuzzy system for females in 2 age group is much lower than desired.

Successful ratio was calculated as 70% for 0 age group, 77% for 1 age group, 58% for 2 age group, 68% for 3 age group, 58% for 4 age group, 55 for 5 age group, 72% for 6 age group, 62% for 7 age group for males. As seen here, fuzzy system is below the desired accuracy level for males. A new assessment is required for males. Development levels should be analyzed and membership functions should be formed again

.

7. CONCLUSION AND RECOMMENDATIONS

A different solution was aimed for bone age assessments with ‘’bone age assessment with fuzzy logic’’ study. A success in a ratio of 75% was obtained on all samples with the designed fuzzy system and program. Fuzzy system designed for females was observed to be more successful (88% vs. 64%). In terms of human groups, it was most successful in Caucasians (82%).

Success ratio of fuzzy system was found to be higher compared to Tanner –Whitehouse method according to database comparisons. Bone age assessment with subjective assessments that mainly aimed could be estimated with fuzzy system and presented for use via software. Designing a better system is possible with regulations in the fuzzy system. Success ratio of the system that will be designed is expected to be higher according to the result of 373 graphics. Obtaining more accurate results with more trials is expected for the system developed by making improvements with designed test graphics using reference graphics.

Figures and Tables

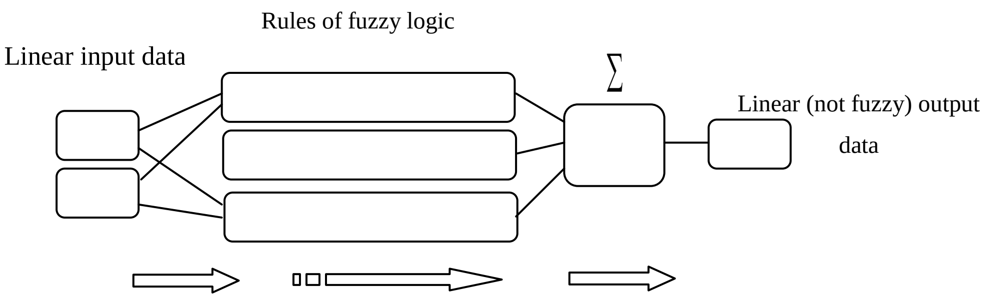

Figure 1. Structure of fuzzy systems

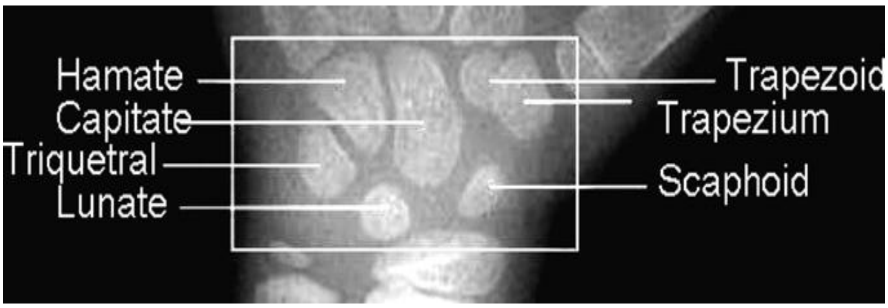

Figure 2. Carpal bones [14]

RA Journal of Applied Research
ISSN (e): 2394-6709
||Volume||3||Issue||12||Pages-1270-1287||December-2017||
Index Copernicus ICV: 74.25, DOI: 10.18535/rajar/v3i12.04

Table 1. Capitates ratio of carpal bone areas in males and females

Age (Year)	Gender	Hamates / Capitates	Triquetral / Capitates	Lunates / Capitates	Scaphoid / Capitates	Trapezium / Capitates	Trapezoid / Capitates
0,66	Male	0,901288	0	0	0	0	0
1	Male	0,736607	0	0	0	0	0
1,5	Male	0,646177	0	0	0	0	0
2	Male	0,726064	0	0	0	0	0
2,5	Male	0,697334	0,239037	0	0	0	0
3	Male	0,768642	0,380497	0,046845	0	0	0
4	Male	0,741652	0,357645	0,214411	0	0	0
5	Male	0,613276	0,340548	0,225108	0	0,084416	0
6	Male	0,692408	0,286649	0,259817	0,140052	0,152487	0,109948
7	Male	0,581556	0,336023	0,356196	0,324496	0,287608	0,163689
8	Male	0,710287	0,413767	0,475038	0,413767	0,399395	0,316944
0,66	Female	0,655488	0	0	0	0	0
1	Female	0,921909	0	0	0	0	0
1,5	Female	0,650588	0	0	0	0	0
2	Female	0,758308	0,365559	0	0	0	0
2,5	Female	0,741107	0,335968	0,192688	0	0	0
3	Female	0,743697	0,368908	0,186555	0	0	0
4	Female	0,577832	0,288509	0,180929	0,05053	0,052975	0,087205
5	Female	0,732036	0,38997	0,317365	0,176647	0,130988	0,141467
6	Female	0,635258	0,332827	0,276596	0,205927	0,382979	0,265198
7	Female	0,652556	0,400958	0,344249	0,36901	0,416933	0,339457
8	Female	0,718299	0,425209	0,486712	0,390281	0,39104	0,338648

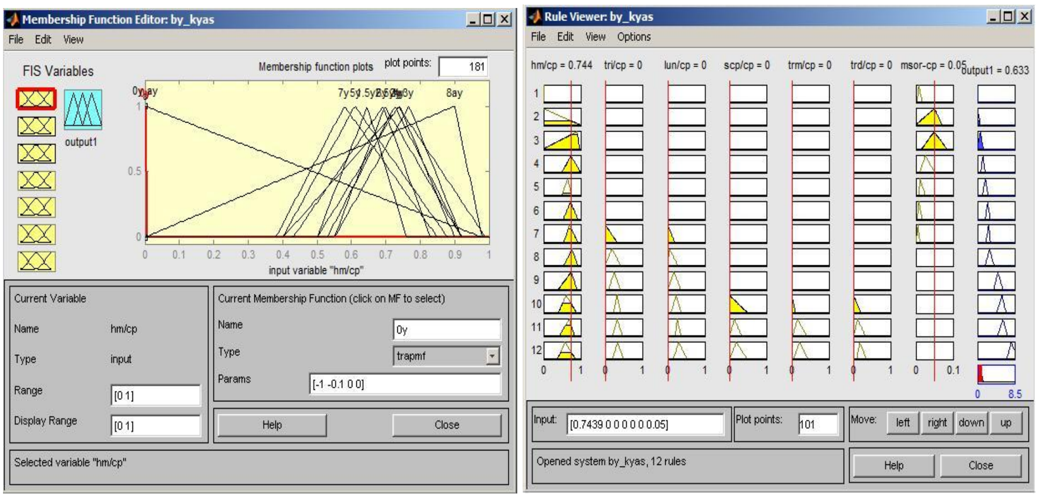

Figure 3. Adjustment of membership functions and fuzzy system rule viewer

RA Journal of Applied Research
ISSN (e): 2394-6709
||Volume||3||Issue||12||Pages-1270-1287||December-2017||
Index Copernicus ICV: 74.25, DOI: 10.18535/rajar/v3i12.04

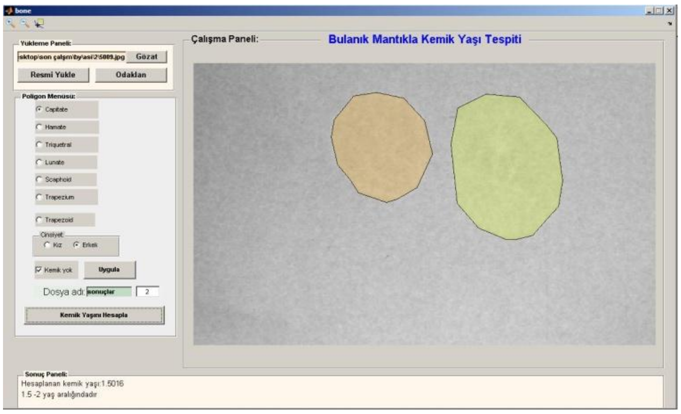

Figure 4. Interface of prepared program, selection of the bones and sending input to the fuzzy system and obtaining output

Table 2. Degree of estimated graphics and percentage according to sum in its group

	Estimated value is poor		Estimated value is good		Estimated value is very good		Fuzzy system reading error		Total
Aisian	14	17%	22	26%	42	50%	6	7%	84
African	18	19%	21	23%	44	47%	10	11%	93
Caucasian	12	12%	17	17%	65	65%	6	6%	100
Hispanic	10	10%	30	31%	41	43%	15	16%	96
Total	54	14%	90	24%	192	51%	37	10%	373

Table 3. Success percentage of estimated graphics according to age

Gender	Age	Estimated value is poor		Estimated value is good		Estimated value is very good		Fuzzy system reading error		Total
Female	0	1	13%	3	38%	4	50%	0	0%	8
Female	1	1	5%	1	5%	16	84%	1	5%	19
Female	2	4	22%	7	39%	6	33%	1	6%	18
Female	3	2	10%	3	15%	15	75%	0	0%	20
Female	4	2	10%	9	45%	9	45%	0	0%	20
Female	5	4	12%	10	30%	19	58%	0	0%	33
Female	6	2	6%	6	19%	22	71%	1	3%	31
Female	7	1	3%	7	21%	24	71%	2	6%	34
Male	0	2	20%	4	40%	3	30%	1	10%	10
Male	1	4	22%	8	44%	6	33%	0	0%	18
Male	2	7	37%	4	21%	7	37%	1	5%	19
Male	3	3	16%	5	26%	8	42%	3	16%	19
Male	4	8	38%	2	10%	10	48%	1	5%	21
Male	5	4	12%	9	26%	10	29%	11	32%	34
Male	6	4	12%	9	27%	15	45%	5	15%	33
Male	7	5	15%	3	9%	18	53%	10	29%	34

Research & Analysis Journals

RA Journal of Applied Research
ISSN (e): 2394-6709
||Volume||3||Issue||12||Pages-1288-1294||December-2017||
Index Copernicus ICV: 74.25, DOI: 10.18535/rajar/v3i12.05

8. REFERENCES

1. Boyunağa Ö (2002). Radyolojik Olarak Kemik Yaşı Tayini. Klinik Pediatri. 1:81-85.
2. Bezdek J (1981). Pattern Recognition with Fuzzy Objective Functions. Plenum Press, New York. pp 20-44.
3. Altaş I (1999). Bulanık mantık: bulanık denetim. Enerji, Elektrik, Elektromekanik - 3e. 64:76-81.
4. Yardımcı A (2009). Soft Computing in Medicine",Applied Soft Computing. 9:1029-1043.
5. Mamdani E (1974). Application of fuzzy algorithms of simple dynamic plant. IEEE Proceeding. 121:1585-1588.
6. Gökalp E, Boz Y (2004). Uyuşumsuz Ölçülerin Belirlenmesinde Bulanık Mantık ve Geleneksel Yaklaşımların İrdelenmesi. TUJK 2004 Yılı Bilimsel Toplantısı Mühendislik Ölçmelerinde Jeodezik Ağlar Çalıştayı, Zonguldak. pp 14-16.
7. Tosun M, , Dincer K. and Baskaya S., (2011). Rule-based Mamdani-type fuzzy modeling of thermal performance of multi-layer precast concrete panels used in residential buildings in Turkey. Expert Systems with Applications. 38:5553–5560.
8. Gilsanz V, Ratib O (2007). Hand Bone Age. Springer. pp 5-17.
9. Spampinato C (2003). Skeletal bone age assessment. Proceedings of ICIP. 1:1077-1080.
10. Greulich WW, Pyle SI (1971). Radiographic atlas of skeletal development of hand and wrist. Stanford University Press, 2nd edition. pp 1-220.
11. Tanner J M, Whitehouse RH (1975). Assessment of Skeletal Maturity and Prediction of Adult Height (TW2 Method). London Academic. pp 22-53.
12. Lin P, Zheng C., Zhang F.,Yang Y., (2005). X-ray carpal-bone image boundary feature analysis using region statistical feature based level set method for skeletal age assessment application. Optica Applicata. 2:1-5.
13. Srivastav A, Saraswat P.K., Agarwal S.K., Gupta P., (2007). A study of wrist ossification for age estimation in pediatric group in Central Rajasthan. Journal of Indian Academy of Forensic Medicine. 26(4):132-135.
14. Zhang A., Gertych A. and Liu B.J., (2007). Automatic bone age assessment for young children from newborn to 7-year-old using carpal bones. Computerized Medical Imaging and Graphics. 31:299–310.
15. Internet (2010). Computer-aided Bone Age Assessment of Children Using a Digital Hand Atlas. Image processing and informatics labs, The University of Southern California. http://www.ipilab.org/Research/BAA/BAAindex.php.