POLİTEKNİK DERGİSİ

JOURNAL of POLYTECHNIC

ISSN: 1302-0900 (PRINT), ISSN: 2147-9429 (ONLINE)

URL: http://www.politeknik.gazi.edu.tr/index.php/PLT/index

Prediction of wood density by using red-green-blue (rgb) color and fuzzy logic techniques

Kırmızı-yeşil-mavi (kym) renk ve bulanık mantık teknikleri kullanılarak odun yoğunluğu tahmini

Yazar(lar) (Author(s)): *Timuçin BARDAK, Selahattin BARDAK*

Bu makaleye şu şekilde atıfta bulunabilirsiniz(To cite to this article): Bardak T., and Bardak S., "Prediction of wood density by using red-green-blue (rgb) color and fuzzy logic techniques", ***Politeknik Dergisi***, 20(4): 979-984, (2017).

Erişim linki (To link to this article): http://dergipark.gov.tr/politeknik/archive

DOI: **10.2339/politeknik.369132**

Prediction of Wood Density by Using Red-Green-Blue (RGB) Color and Fuzzy Logic Techniques

Araştırma Makalesi / Research Article

Timuçin BARDAK[1], Selahattin BARDAK[2*]

[1]Forestry Furniture and Decoration Program, Bartın Vocational School, Bartin University, 74000, Bartın, Turkey

[2]Department of Industrial Engineering, Faculty of Engineering and Architecture, Sinop University, 57000, Sinop, Turkey

(Geliş/Received : 25.11.2016 ; Kabul/Accepted : 14.01.2017)

ABSTRACT

Density is an important wood property since it correlates to mechanical properties of wood. Fuzzy logic, among the various available Artificial Intelligence techniques, emerges as a good technique in predicting. Digital image analysis is an powerful tool to obtain meaningful data out of an image. In this study, digital image processing based on a red–green–blue (RGB) color examination was practiced to measure the intensity of wood color. Densities of the test samples were measured. Then, a new fuzzy logic model was developed based on these measured values and RGB color intensity of wood. Afterwards, the experimental and modeling data results were compared. 98.17% accuracy was observed between the measurement and the fuzzy logic model. Consequently, Fuzzy logic is visable method for the prediction of the wood density.

Keywords: Fuzzy logic, color, wood, density, imaging.

Kırmızı-Yeşil-Mavi (KYM) Renk ve Bulanık Mantık Teknikleri Kullanılarak Odun Yoğunluğu Tahmini

ÖZ

Ahşap malzemenin yoğunluğu ahşabın mekaniksel özelliklerini etkilemesinden dolayı önemlidir. Mevcut yapay zeka teknikleri arasında bulanık mantık tahminlerde iyi bir yöntem olarak ortaya çıkmaktadır. Dijital görüntü tekniği bir görüntüden anlamlı bir bilgi elde etmek için kullanılan güçlü bir yöntemdir. Test örneklerinin yoğunlukları ölçülmüştür. Ayrıca, örneklerin renk yoğunluğunu ölçmek için Kırmızı-Yeşil-Mavi (KYM) renk muayenesine dayanan dijital görüntü analizi uygulanmıştır. Ölçülen değerler ve ahşabın KYM renk yoğunluğu temelinde yeni bir bulanık mantık modeli geliştirilmiştir. Sonrasında deneyler ve model verileri karşılaştırılmıştır. Hazırlanan modelin çıkarımları ile deneysel veriler %98.17 oranında doğruluk göstermiştir. Sonuç olarak, bulanık mantık odun yoğunluğu tahmini için geçerli bir yöntem olduğu tespit edilmiştir.

Anahtar Kelimeler: Bulanık mantık, renk, odun, yoğunluk, görüntüleme.

1. INTRODUCTION

Wood industries are a key component of economic development in the world. The value of final wood produce depends on physical properties. In manufacturing process of many wood products, the density is important element [1].

In recent years, researchers have tried to design and advance automatic systems based on computer vision and artificial intelligence for quality assessment [2]. Color provides helpful information in predicting product quality. Color is significant criteria related to wood value and it is a good pointer for usage. Color representation, the RGB model, which states color as a mixture of red, green and blue three color components, is frequently used to depict color info of an image [3]. Every color in the RGB spectrum is created of dissimilar levels for each of their red, green and blue components. The combination of these prime color elements will affect color outcome [4]. Current image analysis ensures the product quality control without any further information.

Artificial intelligence (ANNs) plays a significant role in engineering practices and have aroused much interest in latest years. Also ANNs have been widely used in the field of wood science [5-8]. A neurofuzzy color segmentation method has been implemented by Ruz, Estevez and Perez. With a set of 900 images, they achieved 95% accuracy in defect detection. [9, 10]. Fuzzy logic is a form of artificial intelligence. The fuzzy Logic approach can be implemented in various applications such as molecular biology, washing machines, air conditioners and timber production. Fuzzy logic is present trend for decision making, classification and prediction where problem can be formulated by mapping input variable with output variable or where simple solution is not present. Fuzzy logic, first developed by Zadeh, a subject can be belong one or more fuzzy set(s) with a degree of membership, instead of categorizing membership as either 'true' or 'false' as in the classical logic system [11]. A fuzzy set process is an operation on fuzzy sets. These processes are generalization of crisp set operations. These three

**Sorumlu Yazar (Corresponding Author)*
e-posta : selahattinbardak@hotmail.com

operations: fuzzification, rule evaluation, and defuzzification [12, 13]. There are three main steps of fuzzy inference system as given in Figure 1 [14].

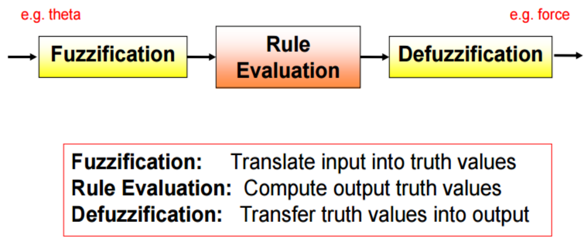

Figure 1. Fuzzy inference system

Studies have exposed that artificial intelligence (Fuzzy Logic and Artificial Neural Networks) model can be productively used to predict in wood applications without needful time-consuming and costly comprehensive experimental investigation. [15-17]. In this paper, we aimed to determine the wood density based on intensity of RGB color on wood surface, develop the calibration equation using color values and evaluate the calibration efficiency by prediction the wood density using Fuzzy logic.

2. MATERIALS AND METHOD

2.1. Materials

The wood species randomly selected in this program is the *Quercus robur* (Pedunculate oak), which is widely used in industry. Air dried samples were cut to nominal dimensions of 25 x 30 x 120 mm. 20 samples were prepared. ASTM D 1666 (2004) and TS 2472 (2005) standards were used to detect the density at 12% moisture contents (MC) [18, 19].

2.2. Vision Acquisition System Design

Before the test, an image analysis set-up was made. The camera (Basler ace camera, 1624 px x 1234 px, acA1600-20gc) was connected fire wire (IEEE1394) protocol to a single desktop computer (CPU i5, 8GB RAM, 1TB Hard Disk Drive (HDD). Images were acquired and examined by means of LabVIEW Vision Builder AI for Windows. National Instruments Vision Builder for Automated Inspection is a configurable machine vision development environment (VBAI) [20-23]. The test setup is given in Figure 2.

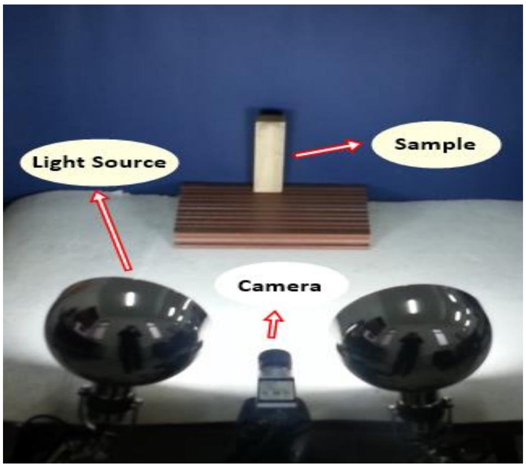

Figure 2. The test setup

The executed color classifier employs RGB color space to calculate a color feature for every sample. Then Red, Green and Blue histograms of the color sample are computed. The values of RGB from the sample's six different surfaces were measured. The average of the surfaces were calculated. Sample sizes and surfaces is given in Figure 3.

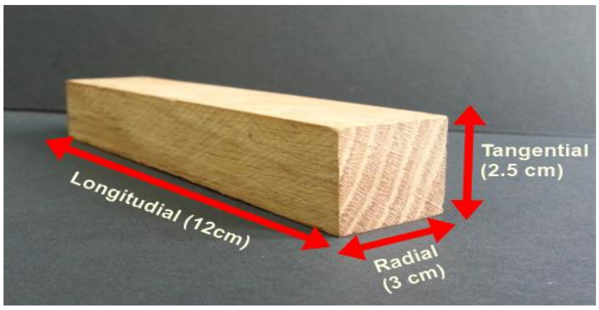

Figure 3. Sample sizes

2.3. Program Setup

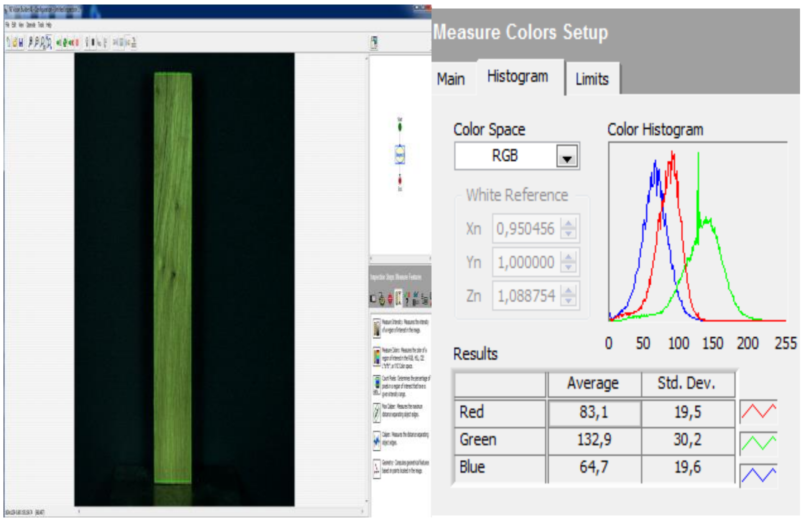

Figure 4. The result and application of the measurement of RGB values based on VBAI for a surface

VBAI was used as the program tool for acquiring and analyzing the images. The program has a wealth of functions separated into five main areas: improve, images, checking presence, locating features, measuring properties and identifying pieces. The result and the application of the measurement of RGB values for a surface based on VBAI is given in Figure 4.

2.4. Data Collection and Pre-processing

The data for fuzzy logic were gathered from VBAI Program. These records were used for training and for testing. The training data set gathered from VBAI Program, is given in Table 1, whereas testing data set given in Table 2.

2.4. Data Collection and Pre-processing

The data for fuzzy logic were gathered from VBAI Program. These records were used for training and for testing. The training data set gathered from VBAI Program, is given in Table 1, whereas testing data set given in Table 2.

Table 1. Training data set (The mean value of red, green and blue of wood samples and density)

Experiment No.	Color Type	Average	Density (g/cm^3)
1	Red	224	0.655
	Green	247	
	Blue	176	
2	Red	207	0.672
	Green	247	
	Blue	159	
3	Red	193	0.690
	Green	241	
	Blue	146	
4	Red	186	0.744
	Green	238	
	Blue	136	
5	Red	177	0.757
	Green	232	
	Blue	126	
6	Red	164	0.814
	Green	223	
	Blue	119	
7	Red	161	0.838
	Green	216	
	Blue	113	
8	Red	160	0.861
	Green	218	
	Blue	115	
9	Red	151	0.876
	Green	209	
	Blue	103	
10	Red	146	0.936
	Green	199	
	Blue	103	

Table 2. Testing data set (The mean value of red, green and blue of wood samples and density)

Experiment No.	Color Type	Average	Density (g/cm^3)
1	Red	198	0.671
	Green	244	
	Blue	146	
2	Red	194	0.682
	Green	243	
	Blue	142	
3	Red	196	0.700
	Green	234	
	Blue	139	
4	Red	188	0.744
	Green	238	
	Blue	135	
5	Red	162	0.838
	Green	215	
	Blue	113	
6	Red	156	0.854
	Green	213	
	Blue	108	
7	Red	153	0.855
	Green	211	
	Blue	106	
8	Red	155	0.861
	Green	214	
	Blue	110	
9	Red	160	0.871
	Green	214	
	Blue	110	
10	Red	148	0.911

2.5. Fuzzy Modeling

The Fuzzy Logic toolbox for Labview was also used for the development of the fuzzy logic rule based system. The fuzzy logic model is going to have three input variables (red, green, and blue) and one output variable (wood density). Input and output values are determined according to the training data. Developed fuzzy logic model structure is given in Figure 5.

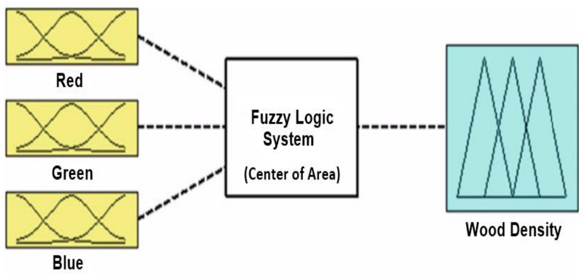

Figure 5. Developed fuzzy logic model structure

Input and output parameters of the model, respectively, are given in Figure 6, 7, 8, and 9.

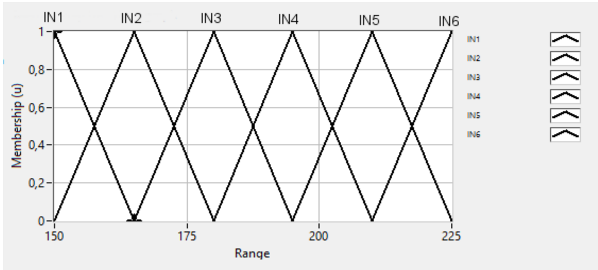

Figure 6. Membership function for red (Input)

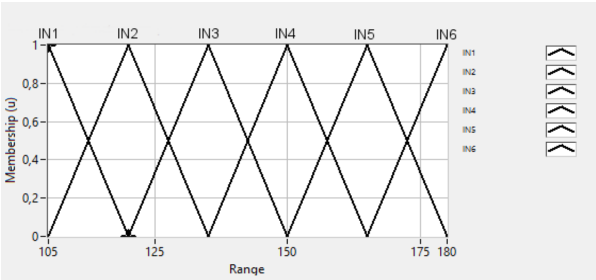

Figure 7. Membership function for blue (Input)

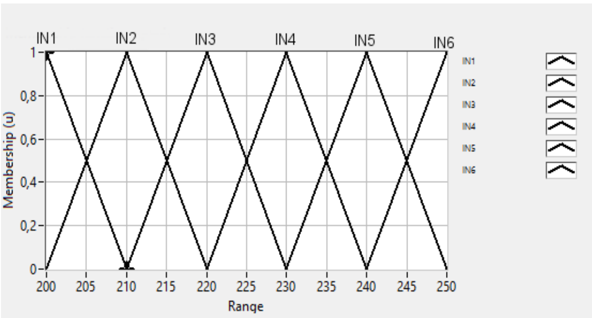

Figure 8. Membership function for green (Input)

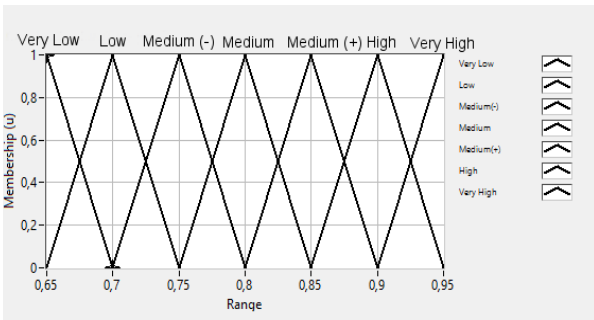

Figure 9. Membership function for wood density (Output)

10 rules written in the fuzzy logic model. Some of the rules are as follows:

1. IF 'Red' IS 'IN6' AND 'Green' IS 'IN6' AND 'Blue' IS 'IN6' THEN 'Density' IS 'Very Low'

2. IF 'Red' IS 'IN5' AND 'Green' IS 'IN6' AND 'Blue' IS 'IN5' THEN 'Density' IS 'Very Low'

3. IF 'Red' IS 'IN4' AND 'Green' IS 'IN5' AND 'Blue' IS 'IN4' THEN 'Density' IS 'Low'

4. IF 'Red' IS 'IN3' AND 'Green' IS 'IN5' AND 'Blue' IS 'IN3' THEN 'Density' IS 'Medium(-)'

5. IF 'Red' IS 'IN3' AND 'Green' IS 'IN4' AND 'Blue' IS 'IN2' THEN 'Density' IS 'Medium(-)'

3. RESULTS AND DISCUSSION

3.1. Experimental and Predicte Values of Wood Density

In the present study, wood density of *Quercus robur* (Pedunculate oak) samples was investigated and predicted by means of the fuzzy logic model. The experimental results and the predicted results for wood density and percentage error ratios are given in Table 3.

Table 3. Experimental and predicted values of wood density and their percentage errors

Experiment No.	Experimental (g/cm^3)	Predicted (g/cm^3)	Error (%)
1	0.671	0.700	-4.377
2	0.682	0.706	-3.581
3	0.700	0.701	-0.143
4	0.744	0.750	-0.871
5	0.838	0.839	-0.088
6	0.854	0.863	-1.115
7	0.855	0.871	-1.913
8	0.861	0.857	0.435
9	0.871	0.850	2.492
10	0.911	0.881	3.306
		Average Error (%)	1.832

Comparison of the results of fuzzy logic model and the measured results of the density of wood testers are shown in Figure 10.

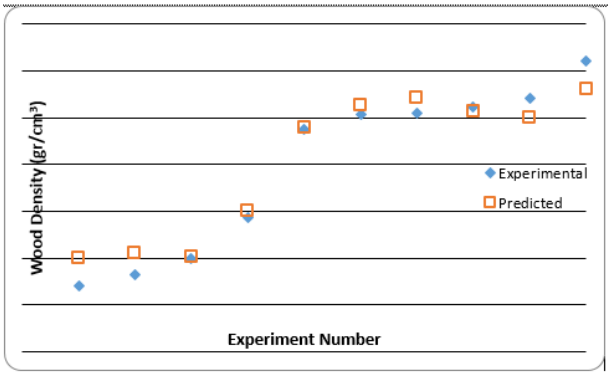

Figure 10. Comparison of the measured values and the predicted values for the wood density

The correlation results obtained with fuzzy logic are quite high. The correlation between measured values and predicted values is 98.17 percent. It can be said that the model has a good performance with this high rate of correlation. At the same time, the results are consistent with the literature [24, 25]. This shows that system using fuzzy logic and color have a high potential of accuracy in predicting wood density. And this system can be used for quality control purposes.

5. CONCLUSION

Wood density values obtained from test results were compared with fuzzy logic system for testing accuracy of the developed model. The outputs of the fuzzy logic model were found to be agreed with experimental outputs. The model was able to predict the density of woods in relation to different RGB values. According to the consequences of comparison, the model concerted well with average experimental results with accurateness level of 98.17 % (wood density) values.

The findings of the present study exhibited that the well-trained fuzzy logic model can minimalize the experimental expenses since it can successfully provide the desired values of wood density with less number of complex test procedures. In addition, image analysis and fuzzy logic can be used in quality control of wood.

REFERENCES

1. Ors Y. and Keskin H., “Wood materials science (Ağaç malzeme teknolojisi)”, ***Gazi University Publication,*** No: 2001-352, Ankara, (2008).
2. Zareiforoush H., Minaei S., Alizadeh M.R. and Banakar A., “A hybrid intelligent approach based on computer vision and fuzzy logic for quality measurement of milled rice”, ***Measurement***, 66: 26-34, (2016).
3. Chen C.L. and C.L. Tai C.L., “Adaptive fuzzy color segmentation with neural network for road detections”, ***Engineering Applications Artificial Intelligence***, 23 (3): 400-410, (2010).
4. Hassan M.A., Yusof Y., Azmi M.A. and Mazli M.N., “Fuzzy Logic Based Intelligent Control of RGB Colour Classification System for Undergraduate Artificial Intelligence Laboratory”, ***The World Congress on Engineering***, London, 713-718, (2012).
5. Tou J.Y., Lau P.Y. and Tay Y.H., “Computer vision–based wood recognition system”, ***International Workshop on Advanced Image Technology (IWAIT)***, Bangkok, Thailand, 197–202, (2007).
6. Esteban L.G., Fernández F.G., Palacios P. and Conde M., “Artificial neural networks in variable process control: application in particleboard manufacture”, ***Investıgacıon Agrarıa-Sıstemas Y Recursos Forestales***, 18(1): 92–100, (2009).
7. Khalid M., Lee E.L.Y., Yusof R. and Nadaraj m., “Design of an intelligent wood species recognition system”, ***International Journal of Simulation: Systems, Science and Technology,*** 9(3): 9–19, (2008).
8. Ozsahin S., “Optimization of process parameters in oriented strand board manufacturing with artificial neural network analysis”, ***European Journal of Wood and Wood Products,*** 71(6): 769-777, (2013).
9. Ruz G.A., Estévez P.A., and Perez C.A., “A neurofuzzy color image segmentation method for wood surface defect detection”, ***Forest Products Journal,*** 55(4): 52-58, (2005).
10. Cavdarlı M. and Seke E., “Measuring roughness on wood surfaces for detection of defects using multi-frame imaging”, ***The International Symposium on Innovations in Intelligent Systems and Applications***, Kayseri, 21-23, (2010).
11. Cheung W.W.L., Pitcher T.J. and Pauly D., “A fuzzy logic expert system to estimate intrinsic extinction vulnerabilities of marine fishes to fishing”, ***Biological Conservation,*** 124(1): 97-111, (2005).
12. Uraon K.K. and Kumar S., “Analysis of Defuzzification Method for Rainfall Event”, ***International Journal of Computer Science and Mobile Computing,*** 5(1): 341–354, (2016).
13. URL1,https://en.wikipedia.org/wiki/Fuzzy_set_operations#Fuzzy_unions. (Accessed 9 Semtember 2016).
14. URL2,http://www.massey.ac.nz/~nhreyes/MASSEY/159741/Lectures/Lec2012-3-159741-FuzzyLogic-v.2.pdf. (Accessed 9 September 2016).
15. Bardak S., Tiryaki S., Nemli G. and Aydın A., “Investigation and neural network prediction of wood bonding quality based on pressing conditions”, ***International Journal of Adhesion and Adhesives***, 68: 115-123, (2016).
16. Tiryaki S. and Hamzacebi C., “Predicting modulus of rupture (MOR) and modulus of elasticity (MOE) of heat treated woods by artificial neural networks”, ***Measurement,*** 49: 266-274, (2014).
17. Tiryaki S., Bardak S. and Bardak T., “Experimental investigation and prediction of bonding strength of Oriental beech (Fagus orientalis Lipsky) bonded with polyvinyl acetate adhesive”, ***Journal of Adhesion Science and Technology,*** 29(23): 2521-2536, (2015).
18. ASTM D1666 – 87, “Standard Methods for conducting Machining Tests of Wood and Wood-Base Materials”, (2004).
19. TS 2472, “Wood Determination of density for physical and mechanical tests”, (2005).

20. Nopens I., Foubert I., Graef V.D., Laere D.V. Dewettinck K. And Vanrolleghem P., "Automated image analysis tool for migration fat bloom evaluation of chocolate coated food products", ***Journal of Food Science and Technology,*** 4:1884–1891, (2008).

21. Nian C.Y., Chuang S.F. and Tarng Y.S., "A new algorithm for a three-axis auto-alignment system using vision inspection", ***Journal of Materials Processing Technology,*** 171: 319–329, (2006).

22. Lv B., Li B., Chen S., Chen J. and Zhu B., "Comparison of color techniques to measure the color of parboiled rice", ***Journal of Cereal Science,*** 50(2): 262-265, (2009).

23. Thalmann C., Freise J., Heitland W. and Bacher S., "Effects of defoliation by horse chestnut leafminer (*Cameraria ohridella*) on reproduction in Aesculus hippocastanum", ***Trees,*** 17: 383–388, (2003).

24. Akkurt, S., Tayfur, G. and Can, S., "Fuzzy logic model for the prediction of cement compressive strength" ***Cement and Concrete Research,*** 34(8):1429-1433, (2004).

25. Ozcifci, A., Yapici, F. and Altun, S., "The prediction of effect of grain angle over modulus of rupture and modulus of elasticity values on Scotch pine with Fuzzy logic classifier" ***5th International Advanced Technologies Symposium (IATS'09),*** Karabuk, 13-15, (2009).