fuzzy logic algorithms can be applied in developing flight simulators for all types of aircraft and be acceptable for aircraft modeling and identification based on the known flight tests data.

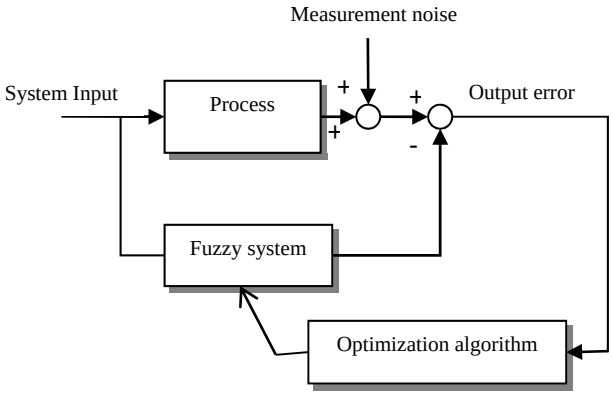

Fig.1 Basic scheme of the identification model for the nonlinear dynamic system using fuzzy logic algorithms.

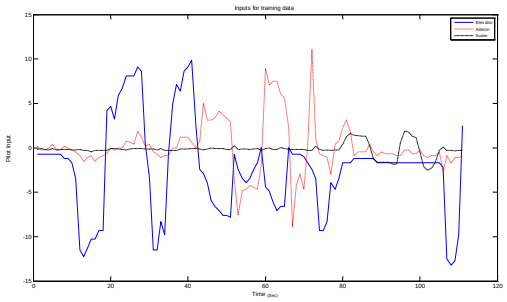

Fig.2. Three-channel series multistep input for training experimental flight test data

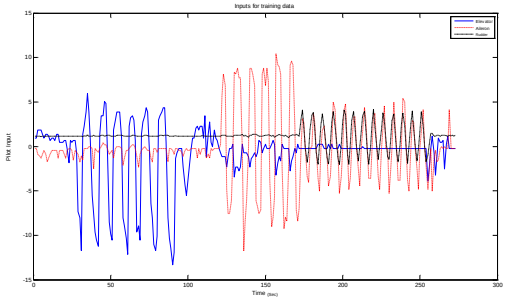

Fig.3. Three-channel series sinusoidal input for training experimental flight test data

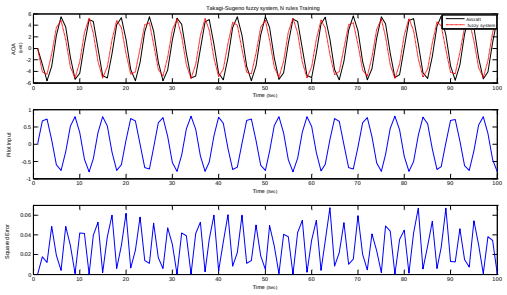

Fig.4. Training results of the AOA for simulation data with sinusoidal input

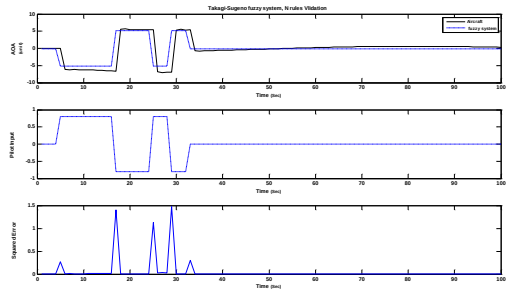

Fig.5. Training results of the AOA for simulation data with multistep input

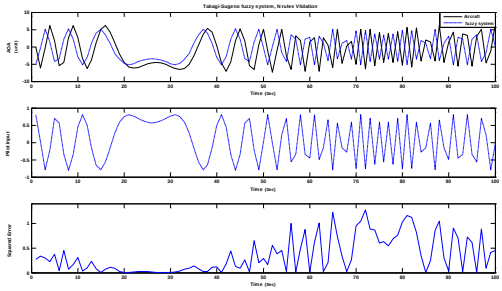

Fig.6. Validating results of the AOA for simulation data

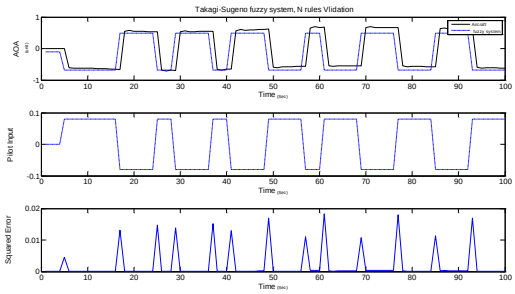

Fig.7. Validating results of the AOA for simulation data

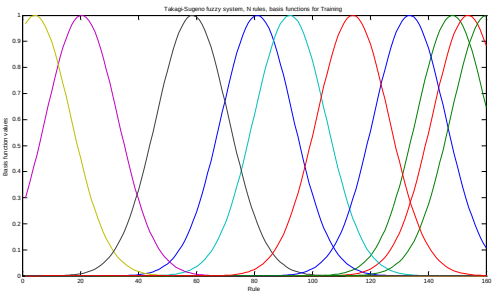

Fig.8. Membership functions activity for AOA in Takagi-Sugino fuzzy system

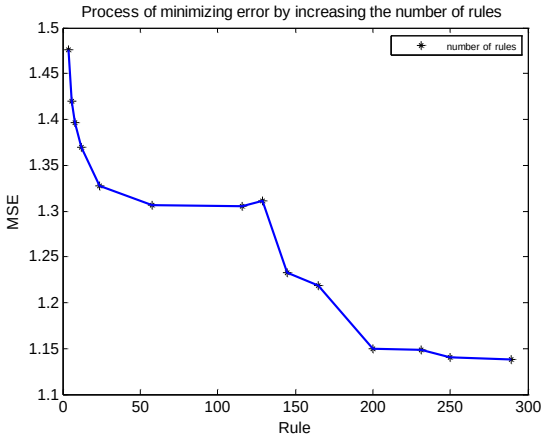

Fig.9. Process of minimizing error by increasing the number of rules for AOA in Takagi-Sugino fuzzy system

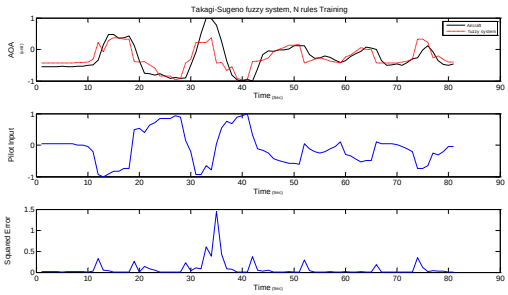

Fig.10. Results of aircraft AOA experimental data training by elevator input in Takagi-Sugino fuzzy system with multistep signal

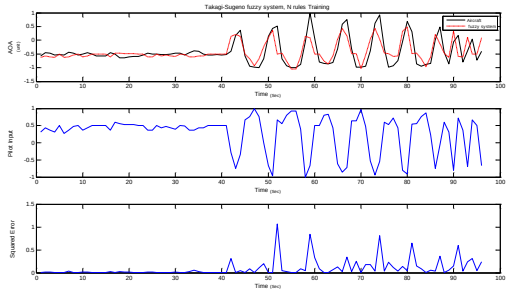

Fig.11. Results of aircraft AOA experimental data training by elevator input in Takagi-Sugino fuzzy system with multistep signal

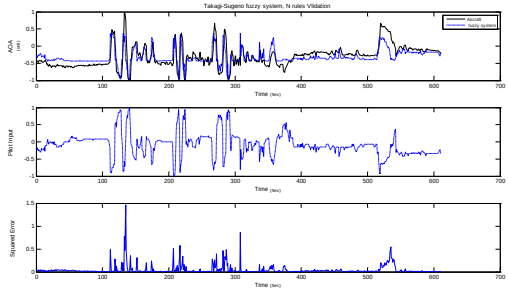

Fig.12. Comparing aircraft AOA experimental data by Takagi-Sugino fuzzy system with a new input

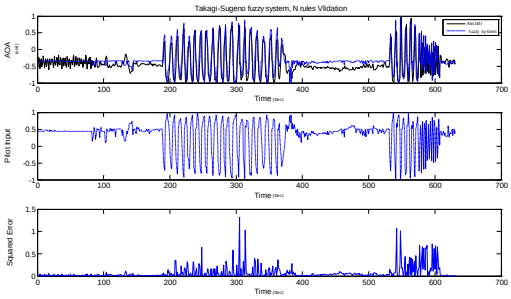

Fig.13. Comparing aircraft AOA experimental data by Takagi-Sugino fuzzy system with a new input

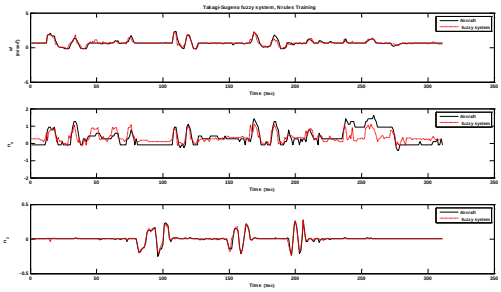

Fig.14. Results of aircraft linear accelerations training by experimental data in Takagi-Sugino fuzzy system

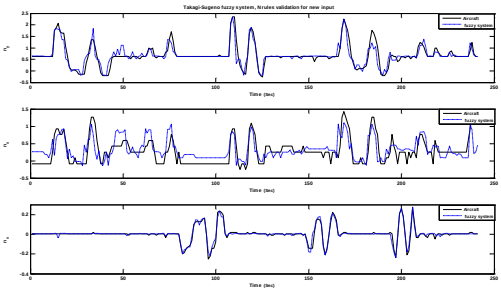

Fig.15. Results of aircraft linear accelerations validating data by experimental data in Takagi-Sugino fuzzy system

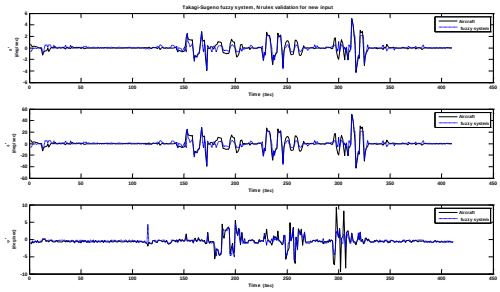

Fig.16. Results of aircraft angular accelerations validating by experimental data in Takagi-Sugino fuzzy system

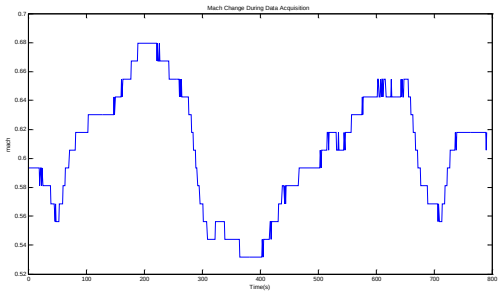

Fig.17. Mach changes for data test

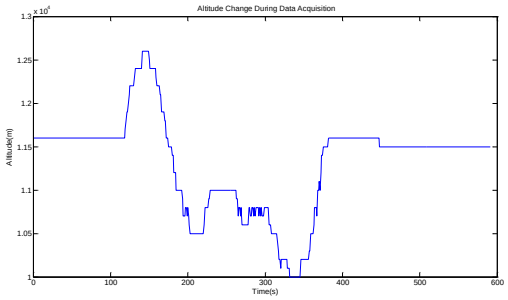

Fig.18. Altitude changes for training data

TABLE I. MSE OF TRAINING AND VALIDATING OF IDENTIFIED MODEL FOR EXPERIMENTAL FLIGHT DATA

States	Training MSE	Validating MSE
θ	1.238	0.8134
ψ	0.0060	0.0038
ϕ	0.0038	0.2474
N_x	0.1137	0.756
N_y	0.0629	0.424
N_z	0.0045	0.0024
α	1.369	1.081

REFERENCES

[1] P. H. Zipfed, Modeling and Simulation of Aerospace Vehicle Dynamics, AIAA Inc., Renson, Virginia, 2000.

[2] J. Roskam, Airplane Flight Dynamics and Automatic Flight Controls, Roskam Aviation and Engineering Corporation, First Edition, USA, 1979.

[3] Tischler MB, Remple RK. Aircraft and Rotorcraft System Identification: Engineering Methods with Flight Test Examples. AIAA Education Series, Reston, VA; 2006.

[4] Ljung L. System identification theory for the user. 2nd ed; 1999.

[5] Nelles O. Nonlinear System Identification– From Classical Approaches to Neural Networks and Fuzzy Models. Springer, New York, NY; 2001.

[6] Klein V, Morelli EA. Aircraft System Identification: Theory and Practice. AIAA Education Series, Reston, VA; 2006.

[7] Tischler MB, Leung JGM, Dugan DC. Frequency-Domain Identification of XV-15 Tilt-Rotor Aircraft Dynamics in Hovering Flight. AIAA 2nd Flight Testing Conference; 83-2695, Las Vegas, Nevada; 1983.

[8] Pintelon R, Schoukens J. System Identification: A Frequency Domain Approach. 1st ed. Wiley-IEEE Press; 2001.

[9] 12. Van Overschee P, De Moor B. Subspace Identification for Linear Systems: Theory, Implementation, Applications. Kluwer, Academic, Dordrecht, the Netherlands; 1996.

[10] Beaulieu MN, De Je susMota S, Botez RM. Identification of structural surfaces' positions on an F/A-18 using the subspace identification method from, Automated Production Engineering,. Proceedings of The Institution of Mechanical Engineers Part G-journal of Aerospace Engineering, 2007; 221(5), pp. 719-731.

[11] Chen S, Billings SA, Grant PM. Non-linear system identification using neural networks. International Journal of Control 1990; 51(6): 1191–1214.

[12] Boëly N, Botez RM. New Approach for the Identification and Validation of a Nonlinear F/A-18 Model by Use of Neural Networks. IEEE Transactions on neural networks 2010; 21(11).

[13] A. Roudbari and F. Saghafi, (2014).Intelligent Modeling and Identification of Aircraft Nonlinear Flight,doi: http://dx.doi.org/10.1016/j.cja.2014.03.017.

[14] Wang LX. Design and analysis of fuzzy identifiers of nonlinear dynamic systems. IEEE Transactions on Automatic Control 1995; 40(1).

[15] 8uuuuuuuuuuuQianqian R, Yi F. Flight Dynamics Identification of a Helicopter in Hovering Based on Flight Data. IEEE International Conference on Artificial Intelligence and Computational Intelligence; 2010.

[16] Raptis IA, Valavanis KP, Moreno W. A.System Identification for a Miniature Helicopter at Hover Using Fuzzy Models. Journal of Intelligent and Robotic Systems 2009; 56: 345-362.

[17] Shaaban A. Salman, Vishwas R. Puttige, Sreenatha G. Anavatti , Real-time Validation and Comparison of Fuzzy Identification and State-space Identification for a UAV Platform, Proceedings of the 2006 IEEE International Conference on Control Applications Munich, Germany, October 4-6, 2006.

[18] Ray C. Chang, Fuzzy Logic-Based Aerodynamic Modeling with Continuous Differentiability, Hindawi Publishing Corporation Mathematical Problems in Engineering Volume 2013, Article ID 609769, 14 pages.

[19] N. Boëly, R. M. Botez and G. Kouba. (2011). Identification of a nonlinear F/A-18 model by use of fuzzy logic and neural network methods, Proceedings of the Institution of Mechanical Engineers, Vol. 225, Part G, Journal of Aerospace Engineering, pp. 559-574.

[20] Sefer Kurnaz·Omer Cetin·Okyay Kaynak, Fuzzy Logic Based Approach to Design of Flight Control and Navigation Tasks for Autonomous Unmanned Aerial Vehicles,

[21] Chung-Shi Tseng, Bor-Sen Chen, Fuzzy Tracking Control Design for Nonlinear Dynamic Systems via T–S Fuzzy Model, IEEE TRANSACTIONS ON FUZZY SYSTEMS, VOL. 9, NO. 3, JUNE 2001.

[22] Vishnu G Nair, Dileep M V, Prahalad K R, Design of Fuzzy Logic Controller for Lateral Dynamics Control of Aircraft by Considering the Cross-Coupling Effect of Yaw and Roll on Each Other. International Journal of Computer Applications (0975 – 888) Volume 47– No.13, June 2012.

[23] Passino, K.M., Yurkovich, S. "Fuzzy Control. Prentice Hall, Englewood Cliffs" (1998).

[24] Stevens, B.L., Lewis, F.L., Aircraft Control and Simulation, John Wiley and Sons Inc,

[25] Plaetschke E., Mulder J.A., Breeman J.H., "Flight test results of five input signals for aircraft parameter estimation", Proceedings of the IFAC Symposium on Identification and System Parameter Estimation, Washington, D.C., Vol.2, January1982,PP.1149-1154.

[26] Klein V, Moreli EA. Aircraft System Identification Theory and Practice. AIAA Education Series .