ISSN: 0975-833X

Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 8, Issue, 12, pp.43560-43564, December, 2016

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

RESEARCH ARTICLE

A NOVEL MEMORY POLYNOMIAL BEHAVIORAL MODELING DIGITAL PRE-DISTORTION TECHNIQUE BASED ON METAHAUSTRIC HYBRID MEMTIC ALGORITHM

***Harjinder Singh and Amandeep Singh Sappal**

Department of ECE, Punjabi University, Rajpura Road, Patiala, Punjab, India

ARTICLE INFO

Article History:

Received 23rd September, 2016
Received in revised form
12th October, 2016
Accepted 19th November, 2016
Published online 30th December, 2016

Key words:

Digital predistorter,
Memory effects,
Memory polynomial,
Non-linearity,
Power amplifier,
Metahaustric hybrid memtic algorithm
WiMAX.

ABSTRACT

This paper introduces a low-complexity metahaustric hybrid memtic algorithm optimization based model coefficients extraction solution for digital pre-distortion (DPD) technique of radio frequency (RF) power amplifier (PA). The proposed modified memory polynomial behavioral modeling digital pre-distortion technique uses indirect learning architecture. The model requires a very low number of numerical operations per iteration, leading to considerable reduction in implementation complexity. The simulation results for Worldwide Interoperability of Microwave Access (WiMAX) 10 MHz PA system show the extraction solution achieves excellent linearization accuracy.

Citation: ***Harjinder Singh and Amandeep Singh Sappal*, 2016.** "A novel memory polynomial behavioral modeling digital pre-distortion technique based on metahaustric hybrid memtic algorithm", *International Journal of Current Research*, 8, (12), 43560-43564.

INTRODUCTION

To effectively apply DPD technique, at the first the nonlinear PA model with memory effects is accurately developed and its characteristics (AM-AM and AM-PM) are correctly reversed, then overall response of the system to a signal flowing serially through the cascade of DPD-PA becomes linear (Shen *et al.,* 2012; Ghannouchi and Hammi, 2009; Bösch and Gatti, 1989). In communication applications, the PA is a key element that influences the overall performances of the system in terms of both linearity and efficiency. In the presence of wideband signals (WiMAX) the PA behaves as a dynamic nonlinear system that exhibits static distortions and memory effects (Morgan *et al.,* 2006; Rajbir Kaur, 2016; Yao *et al.,* 2005). . DPD widely used at transmitting end and a tradeoff between computational cost and accuracy. In the present work improved DPD method that enhances the linearity performance of a PA while reducing the complexity(Rajbir Kaur, 2016; Zhang *et al.,* 2015). The proposed DPD technique is based on metahaustric hybrid memtic algorithm with an indirect learning architecture. The proposed HMA algorithm HMA, in this section TSA and MA are hybridised (Qingqiang Guo *et al.,* 2012; Amandeep Singh Sappal *et al.,* 2011). It was derived from the simultaneous, proposed HMA to determine the coefficient and finally find the optimum solution. The adjacent leakage ratio (ACLR), error vector magnitude (EVM) and number of PA and DPD coefficients are calculated. The first section of this paper is introduction. Section 2 describes memory polynomial modeling of PA and DPD, section3contains hybrid memtic algorithm and its explanation, simulation results are described in section. And the last section of this paper contains the conclusion (Amandeep Singh Sappal *et al.,* 2011; Nikolai Wolff *et al.,* 2016).

***Corresponding author: Harjinder Singh**
Department of ECE, Punjabi University, Rajpura Road, Patiala, Punjab, India

Memory Polynomial Model

The memory polynomial expression implemented in the proposed work is given for the output is given (Bösch and Gatti, 1989; Rajbir Kaur, 2016; Amandeep Singh Sappal *et al.,* 2011)

$$y_{MP}(n) = \sum_{k=0}^{K-1}\sum_{l=0}^{L-1} c_{l,k}\, x(n-l)\left|x(n-l)\right|^{k} \tag{1}$$

where the signals $x(n)$ and $y_{MP}(n)$ are the complex baseband input and output waveforms, respectively, and $c_{l,k}$ represents the model's coefficients. L represents memory length and K is the order of non-linearity. The output of a PA and DPD modeledusing memory polynomial model can be written in vector form as (Rajbir Kaur, 2016; Hertz and de Werra (1991)

$$y_{MP}(n)=\mathbf{u}(n)\mathbf{c} \tag{2}$$

Estimation of the coefficients $c_{l,k}$ can be carried out by considering the solution of equation 5.1 as solution of linear equation;

$$\mathbf{A}x=\mathbf{B} \tag{3}$$

In objective function (equation 5.2) the values of x i.e. $c_{l,k}$ can be estimated by minimizing the error between modeled and actual PA/DPD.

$$e=\text{ minimize }\|Ax-b\|=\left(\sum\left(y_{MP}(n)-y(n)\right)^2\right)^{1/2} \tag{4}$$

In present work hybrid MA metaheuristic optimization algorithm has been used to model PA and DPD (Rajbir Kaur, 2016; Li Gan, 2009) .

Hybrid Memetic Algorithm

Optimization is the goal of the algorithms, it is common practice to hybridise evolutionary algorithms when using them in a real problems. To develop the new algorithm HMA, in this section tabu search algorithm (TSA) and memtic algorithm (MA) are hybridised (Glover and Laguna, 1993; Qingqiang Guo *et al.,* 2012) . This may involve the use of operators from TSA and MA which have already been used in modelling, or the incorporation of domain specific knowledge. Operators are used in HMA are; tl is tabu lists, $tl_{\min}$ is the initial length of tabu list, $tl_{\max}$ is the max length of tabu list, $InList$ is adopted keep the records of removed edges, $OutList$ is adopted keep the records of added edges. Tabu tenure, determined by the length of tl , is a period for which it forbids edges in the tl from adding or deleting. The lengths of tabu lists are dynamic in proposed algorithm, which help the local search implement centralization and diversification strategies. If the best solution in this iteration has not been updated for $nic_{\max}$ movements, the length of tabu lists will be increased by tl_{inc} . The search stops if the length of either of tl is larger than $tl_{\max}$. In HMA, MA is used as a diversification strategy for TSA without loss of generality. The flowchart of the proposed algorithm is shown in figure 1 (Rajbir Kaur, 2016; Katagiri *et al.,* 2009). The solutions representation of TSA and MA are already described in so many optimization problems. Tabu Search and Memetic Algorithm have their own advantages on solving optimization problems. Before proceeding to the description of metheuristic methods, we firstly focus on local search. MA is to be orders of magnitude faster and more accurate than other algorithms (Hertz and de Werra (1991) and Qingqiang Guo *et al.,* 2012). It has been applied widely to solve optimization problems because of their good search abilities. However, they may not be efficient to several problems which contain many local optima. The most important characteristic of TSA is that it uses a concept of memory to control movements via a dynamic list of forbidden moves. This mechanism allows TSA to strengthen or diversify its search procedure in order to escape from local optima.

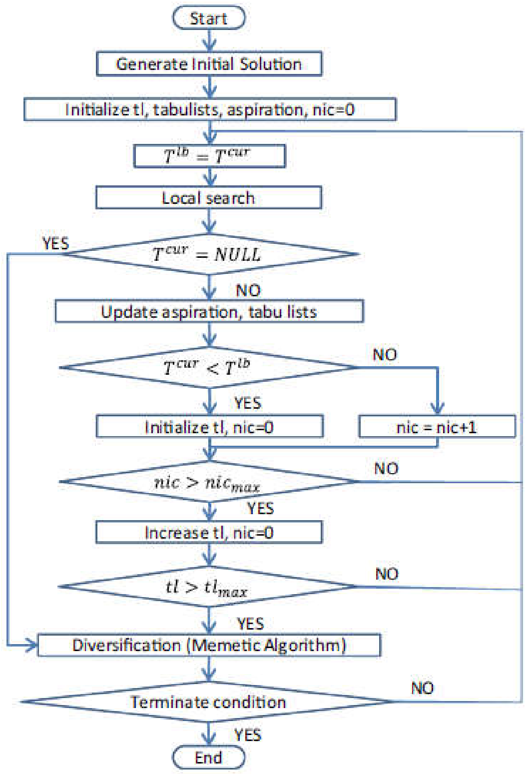

Figure 1: Flow diagram of Hybrid Memetic Algorithm

If a solution could not be improved any more by TSA, it would like to try MA as a diversification strategy to improve the solution once more. This procedure is used to make the algorithm escape from local optimum by evolutionary computation operators. The Algorithm of is given as (Katagiri *et al.,* 2009; Qingqiang Guo *et al.,* 2012).

Hybrid Memetic Algorithm

Step 1 $P\ := Initialize\left(P\right)$

while stop criterion not satisfied do

Step 2 $P' := Genetic\ Operations\left(P\right)$

Step 3 $P' := UpdatingPopulation\left(P'\right)$

Step 4 $P' := Replace\left(P\cup P'\right)$

Step 5 $P'' := Tabu\ Search\ based\ Local\ Search\left(P'\right)$

Step 6 $P'' := UpdatingPopulation\left(P''\right)$

Step 7 $P\ := Replace\left(P\cup P''\right)$

endwhile

Step 8 $Return\left(P\right)$

Where P means the population of individuals now, $'P'$ means the individuals which are generated from the Genetic Operations, and P'' denotes the individuals improved by Tabu Search based Local Search. This new approach used for optimization to improve the modeling accuracy. The fitness function is the result of applied heuristic in the term of number of values Rajbir Kaur (2016), Hertz and de Werra (1991) and Qingqiang Guo *et al.,* 2012.

SIMULATION RESULTS

This section illustrates the results obtained by using HMA. To validate the performance of the HMA, the PA and DPD was modeled using the memory polynomial model given by equation 1. All the characteristics of proposed algorithms for PA and DPD have been measured by sweeping value of memory length L between 1 to 5 and the nonlinearity order K between 2 to 7 in memory polynomial.

PA modeling using HMA

Figure 2 and figure 3 shows the AM-AM characteristics and the AM-PM characteristics respectively of actual PA and proposed HMA PA model, the characteristics curve of proposed HMA PA model is tried to follow the characteristics of actual PA. This shows the accuracy of the modeling in terms of AM-AM and AM-PM characteristics.

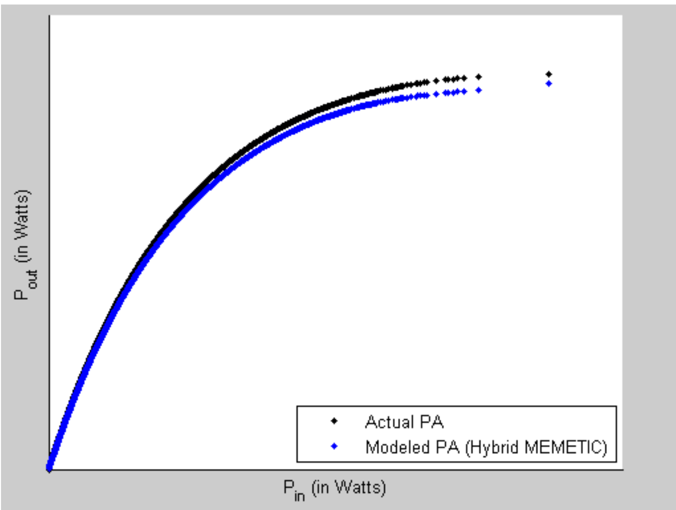

Figure 2: AM-AM characteristics for actual PA and proposed HMA PA model

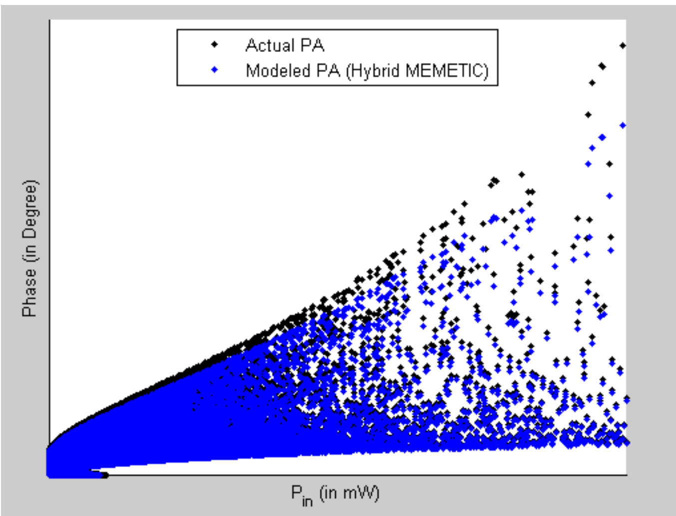

Figure 3: AM-PM characteristics for actual PA and proposed HMA PA model

Figure 4 shows the power spectral density diagram of actual PA and proposed HMA PA model, due to PA memory and non-linear effects, the spectrum of output signal has expanded.

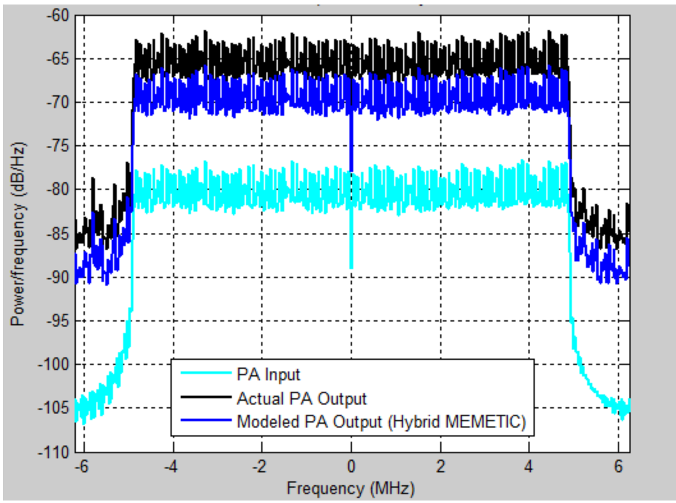

Figure 4: Power spectral density of actual and proposed HMA PA model

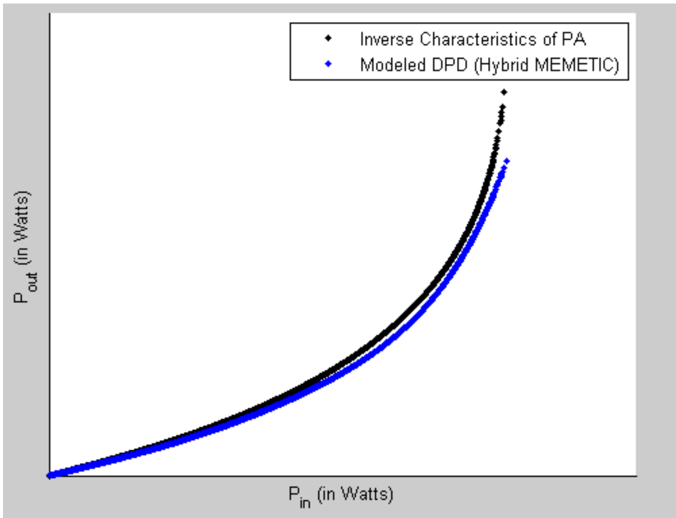

Figure 5: AM-AM characteristics for proposed HMA PA model and inverse AM-AM characteristics of actual PA

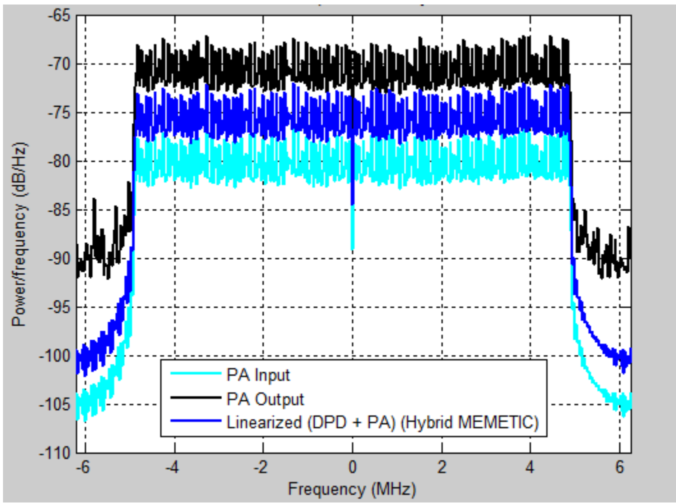

Figure 6: Power spectral density of actual and modelled PA, modelled (DPD+PA) using proposed TS

The performance of proposed HMA PA model based on ACLR (dB), EVM (dB), memory length and non linear order can be inferred from table 5.10. The ACLRs of actual PA are Lower Channel 2 (53.17), Lower Channel 1 (28.28), Upper Channel 1 (29.04) and Upper Channel 2 (54.01). The ACLRs of modeled PA using H-MA is Lower Channel 2 (55.24), Lower Channel 1 (29.36), Upper Channel 1 (28.74) and Upper Channel 2

Table 1: Measurements of actual PA and proposed HMA modeled PA

Type	Adjacent Channel Leakage Ratio (dB)				Error Vector Magnitude (dB)	Memory length	Non linear order
	Lower Channel 2	Lower Channel 1	Upper Channel 1	Upper Channel 2			
Actual PA	53.17	28.28	29.04	54.01	-24.28	-	-
H-MA PA	55.24	29.36	28.74	55.09	-25.14	3	7

Table 2: DPD Performance Metrics using using proposed HMA modeled DPD

Type	Adjacent Channel Leakage Ratio (dB)				Error Vector Magnitude (dB)	Memory length	Non line order
	Lower Channel 2	Lower Channel 1	Upper Channel 1	Upper Channel 2			
Actual PA	53.17	28.28	29.04	54.01	-24.28	-	-
H-MA DPD	80.07	56.18	56.97	80.73	-28.26	5	7

(55.09). From table 1, it has been concluded that all ACLRs of HMA modelled PA have closer to the ACLRs of actual PA. For HMA PA model, the values of memory length L and the nonlinearity order K are 3 and 7 respectively so, the no of coefficients are 21 in HMA PA model. The EVM of actual PA and HMA are -24.28 and -25.14 respectively, so the EVM of HMA PA model (-25.14) is also closer to EVM of actual PA (-24.28).

DPD modeling using HMA

Figure 5 shows the inverse AM-AM characteristics of actual PA and proposed HMA DPD model. The characteristics curves of proposed HMA modeled digital predistorter is tried to follow the inverse characteristics of actual PA, this shows the accuracy of the modeled HMA digital predistorter.

Figure 6 shows the power spectral density diagram of actual PA and digital predistorters of proposed HMA, due to PA memory and non-linear effects, the spectrum of output signal has expanded. The performance comparison of the proposed HMA digital predistorters based on ACLR (dB), EVM (dB), memory length and non linear order can be inferred from table 2. The ACLRs of modeled digital predistorter using H-MA is Lower Channel 2 (80.07), Lower Channel 1 (56.18), Upper Channel 1 (56.97) and Upper Channel 2 (80.73). The ACLRs of actual PA are Lower Channel 2 (53.17), Lower Channel 1 (28.28), Upper Channel 1 (29.04) and Upper Channel 2 (54.01).

From table 2, it has been concluded that the improvement in all ACLRs (Lower Channel 2 (26.90dB), Lower Channel 1 (27.90dB), Upper Channel 1 (27.93dB) and Upper Channel 2 (26.72dB)) of HMA digital predistorter with respect to the actual PA all ACLRs. For HMA DPD model, the values of memory length L and the nonlinearity order K are 5 and 7 respectively so, the no of coefficients are 35 in HMA DPD model. The EVM of actual PA and HMA PA model are -24.28 and -28.26 respectively, so the EVM (-3.98dB) of HMA DPD model has been improved with respect to the EVM of actual PA. Measurement results show the sovereignty of HMA in PA and DPD modeling.

Conclusion

The PA and DPD model measurement results based on a HMA optimization algorithm shows the sovereignty of algorithm. The performance of proposed algorithm was tested on a wideband radio frequency power amplifier working for a WiMAX communication system. The PA results show the ACLR and EVM of modeled PA are very close to the actual PA, this shows the accuracy of proposed PA model. The DPD results concluded that approximately 28dB improvement in ACLR and EVM has also improved. The number of coefficients are also less in proposed model.

REFERENCES

Amandeep Singh Sappal, Dr.Manjeet Singh Patterh and Dr. Sanjay Sharma 2011. Fast Complex Memory Polynomial Based Adaptive Digital Pre-Distorter. *International Journal of Electronics, (Taylor and Francis),* 98(7), 923-931.

Bösch, W. and G. Gatti, 1989. Measurement and simulation of memory effects in predistortion linearizers. *IEEE Trans. Microwave TheoryTech*, 37(12), 1885–1890.

Ghannouchi, F. M. and O. Hammi, 2009. Behavioral modeling and predistortion. *IEEE Microwave Magazine,* 10, 52-64.

Glover, F. and M. Laguna, 1993. Tabu Search, *Modern Heuristic Techniques for Combinatorial Problems,* C. Reeves, ed., Blackwell Scientific Publishing, 70-141.

Harjinder Singh and Amandeep Sappal (2015). Modeling and compensation of thermal effects in power amplifiers. *IEEE Conference in Computing and Communication (IEMCON),* Vancouver, 1-7,

Hertz, A. and D. de Werra 1991. The Tabu Search Metaheuristic: How We Used It, *Annals of Mathematics and Artificial Intelligence*, 1, 111-121.

I. Zhang, Youjiang Liu, Jie Zhou, ShuboJin,Wenhua Chen and Silong Zhang 2015. A Band-Divided Memory Polynomial for Wideband Digital Predistortion With Limited Bandwidth Feedback. *IEEE Transactions on Circuits and Systems-II:* 62(10), 922-925,

Katagiri, H., T. Hayashida, I. Nishizaki and J. Ishimatsu, 2009. A hybrid algorithm based on tabu search and ant colony optimization for kminimum spanning tree problems, *MDAI, Torra, Narukawa and Inuiguchi (eds.),* Springer, Berlin/Heidelberg. pp. 315-326.

Krasnogor N. and Gustafson S. 2012. Toward truly "memetic" memetic algorithms: discussion and proofs of concept, In *Advances in Nature-Inspired Computation: The PPSN VII Workshops. PEDAL (Parallel, Emergent and Distributed Architectures Lab). University of Reading*, pp 16–52.

Li Gan 2009. Adaptive Digital Predistortion of Nonlinear Systems. Doctoral Thesis. *Faculty of Electrical and*

Information Engineering, Graz University of Technology, Austria.

Lie Zhang and Yan Feng 2016. An Improved Digital Predistortion in Wideband Wireless Transmitters Using an Under-Sampled Feedback Loop. *IEEE Communications Letters,* 20(5), 910-913.

Morgan, D. R., Z. Ma, J. Kim, M. G. Zierdt, and J. Pastalan, 2006. A generalized memory polynomial model for digital predistortion of RF power amplifiers. *IEEE Transactions in Signal Processing*, 54, 3852–3860.

NavidLashkarian, Jun Shi, and Marcellus Forbes 2014. A Direct Learning Adaptive Scheme for Power-Amplifier Linearization Based on Wirtinger Calculus. *IEEE Transactions on Circuits and Systems-I,* 61(12), 3496-3505.

Nikolai Wolff, Wolfgang Heinrich and Olof Bengtsson 2016. A Novel Model for Digital Predistortion of Discrete Level Supply-Modulated RF Power Amplifiers. *IEEE Microwave and Wireless Components Letters,* 26(2), 146-148.

Qingqiang Guo, Hideki Katagiri, Ichiro Nishizaki and Tomohiro Hayashida 2012. A Hybrid Algorithm Based on Memetic Algorithm and Tabu Search for *k*-Minimum Spanning Tree Problems. Proceedings of the IMECS 2012, Hongkong. vol 2, pp. 1-6.

Rajbir Kaur, 2016. Design and Implementation of An Efficient Digital Pre-Distorter for Wideband Wireless Transmitters, Doctoral Thesis. *Faculty of Engineering and Technology, Punjabi University, Patiala.*

Shen, Z., A. Papasakellariou, J. Montojo, and F. Xu, 2012. Overview of 3GPP LTE advanced carrier aggregation for 4G wireless communications. *IEEE Communication. Mag*, 50, 122-130.

SouhirLajnef, NoureddineBoulejfen, Abubaker Abdelhafiz and Fadhel M. Ghannouchi 2016. Two-Dimensional Cartesian Memory Polynomial Model for Nonlinearity and I/Q Imperfection Compensation in Concurrent Dual-Band Transmitters. *IEEE Transactions on Circuits and Systems-II,* 63(1), 14-18.

Yao X., Wang F., Padmanabhan K., and S. Salcedo-Sanz S. 2005. Hybrid evolutionary approaches to terminal assignment in communications networks. *Recent Advances in Memetic Algorithms, Studies in Fuzziness and Soft Computing*, 166(0), 129–159.

****