

Figure 2: STFIS controller architecture

C. Presentation of (STFIS)

A sugeno type fuzzy system is determined in three stage [25]:
 1. Given an input x a membership degree μ is obtained from the antecedent part of rules.

2. A truth value degree α_i is obtained, associated to the premises of each rule

R_i : if x_1 is X_1 and if x_2 is X_2 then u is w_i

3. An aggregation stage to take in to account all rules by

$$u = \frac{\sum_{i=1}^r \alpha_i w_i}{\sum_{i=1}^r \alpha_i}$$

These stages can be traduced by the 4 layers structures shown in fig.2.Each layer, connected with others by adjustable parameters, having a specific function.

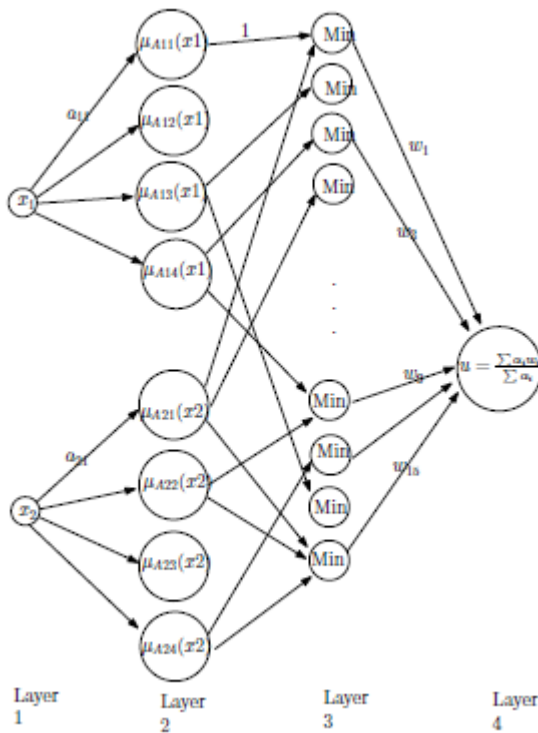


Figure 3:Self Tunable Fuzzy Inference System

D. Algorithm modification weight regression

In this work, we propose to generate the fuzzy control rules by an optimization method. The optimization of adjustable parameter is accomplished with a version of the classic gradient retro-propagation algorithm. The aim is to minimize cost function E:

$$E = \frac{1}{2} \epsilon^2 \tag{30}$$

where ϵ is the difference between set point and process output. The basic equations of the algorithm are:

$$w_{ij}^n(t) = w_{ij}^n(t-1) + \Delta w_{ij}^n(t) \tag{31}$$

$$\Delta w_{ij}^n(t) = -\eta \delta_i^n \alpha_j^{n-1} + b \Delta w_{ij}^n(t-1) \tag{32}$$

where, $w_{ij}^n(t)$: i^{th} parameter between i of layer n and j^{st} unit of layer $n-1$; η :learning again; t :training iteration; b :moment parameter; $\eta \delta_i^n$:error term (i^{th} neuron of layer n); α_j^{n-1} :output of j^{th} unit of layer $n-1$.

The quality of solution obtained using this algorithm depends on input learning signals, algorithm control parameters and learning duration(number of iterations). The procedure is entirely done on line on the actuator. The table of rules (weights w_i) can be initially empty or filled with an a priori knowledge. The actuator acquires by its systems output measures, calculates the error to the back-propagated, updates the triggered rules on-line. The weights of the table of decision are then adjusted locally and progressively. The cost function is given by;

$$J = E + \lambda \sum w_i^2 \tag{33}$$

where E is the classic quadratic error, ware the parameters (weights) to optimize parameters and λ is a constant that controls the growth of parameters. The second term in J is known as weight decay and used usually in the context of classification problems. This technique has been analyzed in the framework of learning theory and it was shown that it is very simple manner to implement a regularization method in a neural network in order to optimize the compromise between the learning error and the generalization error. Due to the classic back propagation algorithm, the parameters as modify as:

$$w(t+1) = w(t) + \eta \left(\frac{\partial J}{\partial w} \right) \tag{34}$$

This algorithm easily includes the effect of the second term of the cost function J and by taking $\beta = 2\lambda\eta$ (regression coefficient) we obtain:

$$w(t+1) = w(t) + \eta \left(-\frac{\partial J}{\partial w} \right) - \beta w(t) \tag{35}$$

Since a fuzzy inference system is concerned, we adapt this formula by multiplying β by the firing term of the rule, namely $\alpha_i / \sum \alpha_i$

α_i is the truth value of the premise part of the triggered rule. If we limit the optimization only on the conclusions parameters w_{1ij}^4 . Then, we get:

$$\Delta w_{1j}^4(t) = -\eta \delta_1^4 \alpha_j^3 + b \Delta w_{1j}^4(t-1) - \frac{\alpha_j^3 2\eta \lambda w_{1j}^4(t-1)}{\sum_k \alpha_k^3} \tag{36}$$

where, $\delta_1^4 = y1 - \frac{y}{\sum_j \alpha_j^3}$;

$y1$:effective output value; y :desired output.

IV. SIMULATIONS RESULTS

Simulation for controller of active half car suspension model is done by using MATLAB simulink. Two type of controller are applied, they are PID controller which is tuned by Zeigler-Nicholas and STFIS. We have considered a total mass of the body equal to $m_b = 1794.4\text{Kg}$.

A fuzzy controller based on an on-line optimization of a zero order Takagi-Sugeno fuzzy inference system is successfully applied. It is used to minimize a cost function that is made up of a quadratic error term and a weight decay term that prevents an excessive growth of parameters of the consequent part. The main idea is to generate the conclusion parts(so-called weight) of the rules automatically thanks to an optimization technique. The use method is based on a back-propagation algorithm where the parameters values are free to vary during the optimization process. The shape of the used membership functions is triangular and fixed in order to extract and represent the knowledge from the final results easily. To reduce the truth value, we use the min operator for the composition of the input variables.

The linguistic labels are defined as follows:

NB: Negative Big, NS: Negative Small, Z:approximately Zero, PS: Positive Small, PB: Positive Big,.

The outputs linguistic labels could be interpreted as follows:

VW: Very Weak, W:Weak,M:Medium, B:Big,VB:Very Big.

de/e	NB	NS	Z	PS	PB
PB	B	B	W	VW	VW
PS	B	B	W	W	VW
Z	VB	B	M	W	VW
NSB	VB	VB	M	W	W
N	VB	VB	B	W	W

Table 1: Learning linguistic table

Fig.4 indicates that the suspension deflection controlled by STFIS smaller than that of passive and PID. From fig.5 and 8,it is observed that the amplitude of the wheel velocity(front and rear) for an active suspension based on STFIS shows considerable improvement compared to the passive travels. Fig.6 and7 illustrates how effectively the active suspension with STFIS absorbs the vehicle vibration compared to the passive system. Finally, fig.9 shows the STFIS controller applied to the half car vehicle. Thus the active suspension with STFIS scheme could greatly contribute to the improvement of the vehicle ride comfort and marginally contribute to the road holding ability.

V. CONCLUSIONS

In this paper, we have presented and implemented an optimization technique allowing an on-line adjustment of the fuzzy controller parameters. The descent gradient algorithm, with its capacities to adapt to unknown situations by the means of its faculties of optimization, and the fuzzy logic, with its capacities of empirical knowledge modeling, are combined to control a new configuration of suspension vehicle. Indeed, we have obtain an on-line optimized Takagi-Sugeno type SIF of zero order. This method is simple,

economical and safe. It leads to very quick and efficient optimization technique. A comparison between the STFIS and the PID controller shows the validity of the proposed and the new technique of the intelligent control. Thus, simulation results demonstrate the effectiveness of the proposed controller. STFIS based active suspension provides higher ride comfort and road handling qualities when compared to existing passive and other classical controller. Future works will essentially investigate the real time implementation of the STFIS and the based model control approaches.

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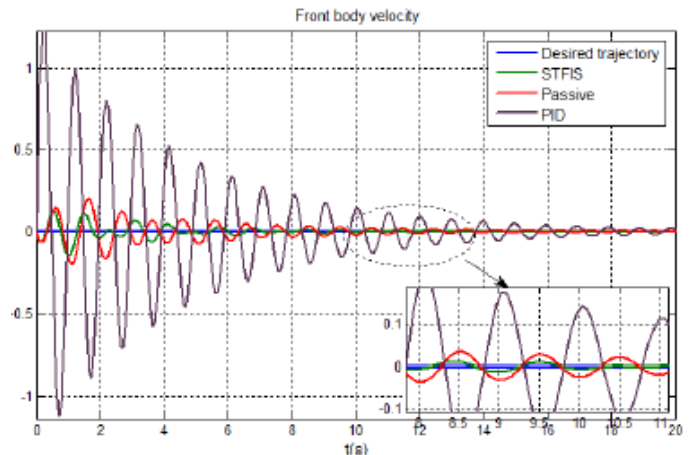


Figure 6: Front body velocity for the half car

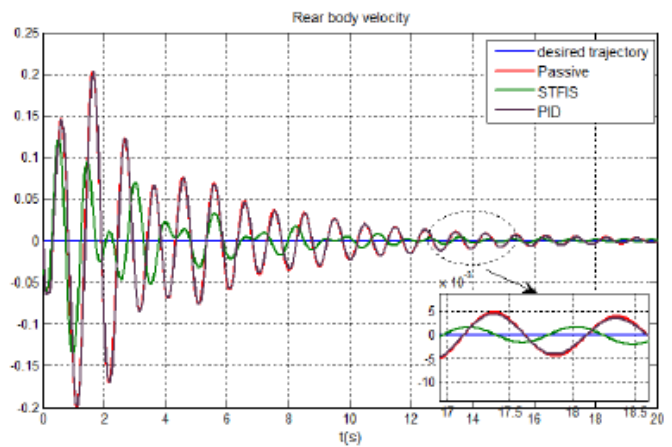


Figure 7: Rear body velocity for the half car

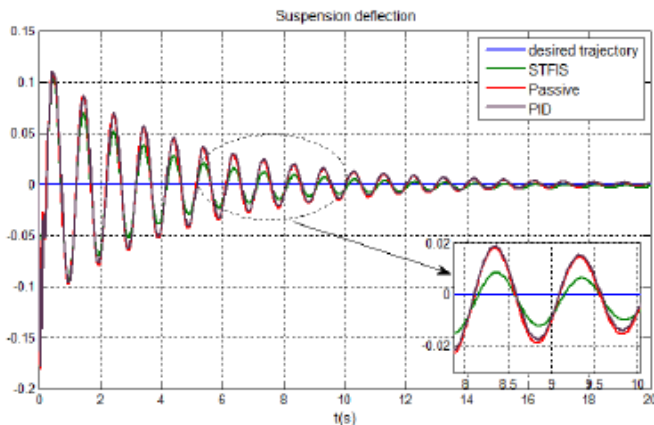


Figure 4: The suspension deflection for the half car

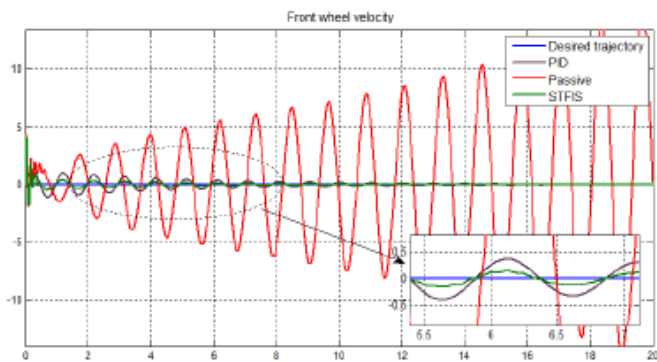


Figure 5: Front wheel velocity for the half car

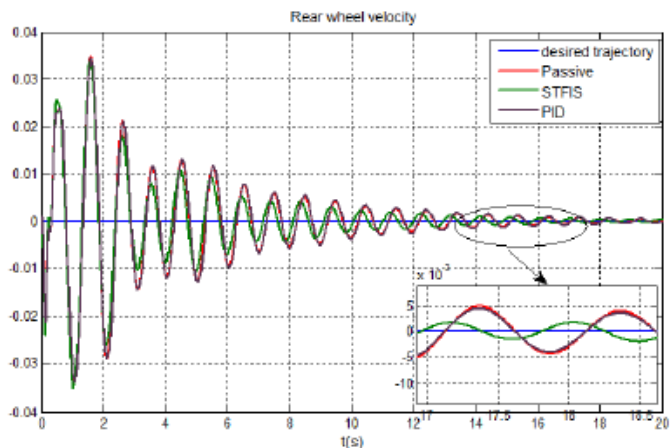


Figure 8: Rear wheel velocity for the half car

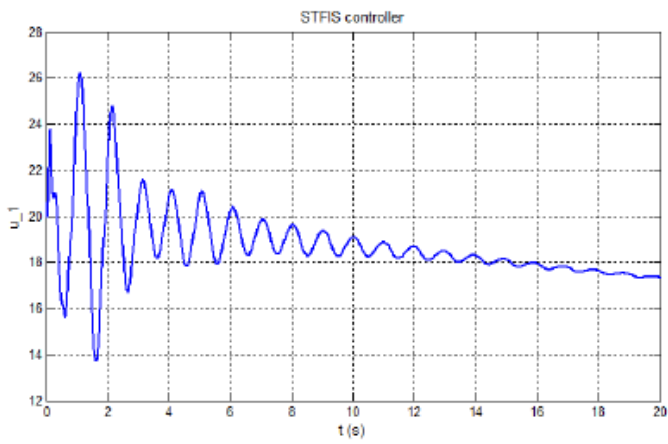


Figure 9: STFIS controller for the half car