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Designing Multi-Stage Fuzzy Guidance Law via Genetic Algorithms

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ABSTRACT

Usually, the parameters of fuzzy guidance laws are generated by trial and error which consumes time and effort and they are not necessary to be optimum [1]. Moreover, they use only one type of guidance through the whole interception range. It was reported in the literature that each of the classical guidance laws have a region of operation where they are superior to other guidance laws [3]

In this paper, a systematic procedure is presented to design an optimal fuzzy-based guidance law for missiles. The proposed law consists of multi fuzzy-based guidance laws which are activated based on the relative distance between the missile and the target.

The rules and the distribution of the membership functions (MF) for the proposed fuzzy controllers are obtained by solving the following optimization problem

$$\min\ f(z) = w_1 t_f + w_2 \int_0^{t_f} u^2 dt + w_3 \left| r(t_f) \right| \tag{1}$$

Subject to

$$\left| r(t_f) \right| < R_{miss-allowed}$$

Where t_f is the interception time, w's are weighting factors, $R_{miss\text{-}allowed}$ is the allowed miss distance, and z is a vector that contains the unknown parameters of the fuzzy system (the rules and the parameters that describe the distribution of membership functions). The optimization problem in Eq (1) is solved by the method of genetic algorithms (GA) [4].

For the design purpose, we consider only the two-dimensional engagement geometry as shown in Figure 2 where the missile and the target are assumed as constant-velocity point masses. The control varaible is the missile accelration (u) which is related to the missile steering angle by the following relation

$$u = V_M \frac{d\dot{\gamma}}{dt} \tag{2}$$

To design a guidance law that has a satisfactory performance over a wide arnge of operating conditions, multiple interception scenarions are used in the evalution of the performance index .

We assume that the missile under consideration has a constant speed of 600 m/sec with maximum range of 3.0 km. The limits of the missile acceleration and miss distance are 30 G (G=9.8 m/sec^2) and 1.0 m respectively. The target speed is 400 m/sec. The best generated normalizad membership functions and guidance rules and are shown in Figure (1) and Table (1) respectively.

Figure (2) shows the response of the missile under the proposed multi-stage fuzzy guidance law (MSFGL) and the proprtional navigation guidance law (PNG) for a

maneuvering target with 15G. The proposed guidance law achieves bettter performance in terms of the interception time, consumed energy, and miss distance.

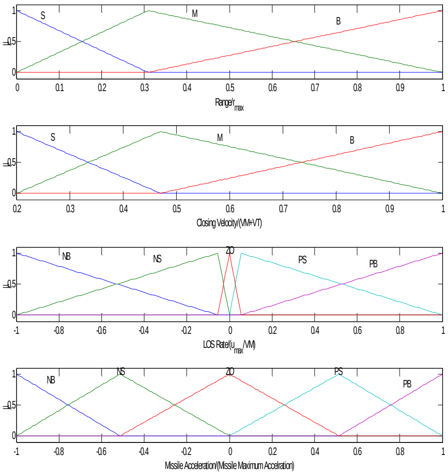

Figure 1: Best generated MF

Table 1: Best Generated Rules

u		$\dot{\theta}$				
r	$V_c = -\dot{r}$	NM	NS	ZO	PS	PB
S	S	NB	NB	ZO	PB	PB
	M	PB	NB	ZO	PB	NB
	B	PS	NB	ZO	PB	NS
M	S	PS	ZO	ZO	ZO	NS
	M	ZO	NB	ZO	PB	ZO
	B	NS	NB	ZO	PB	PS
B	S	NS	NB	ZO	PB	PS
	M	ZO	NB	ZO	PB	ZO
	B	NS	NB	ZO	PB	PS

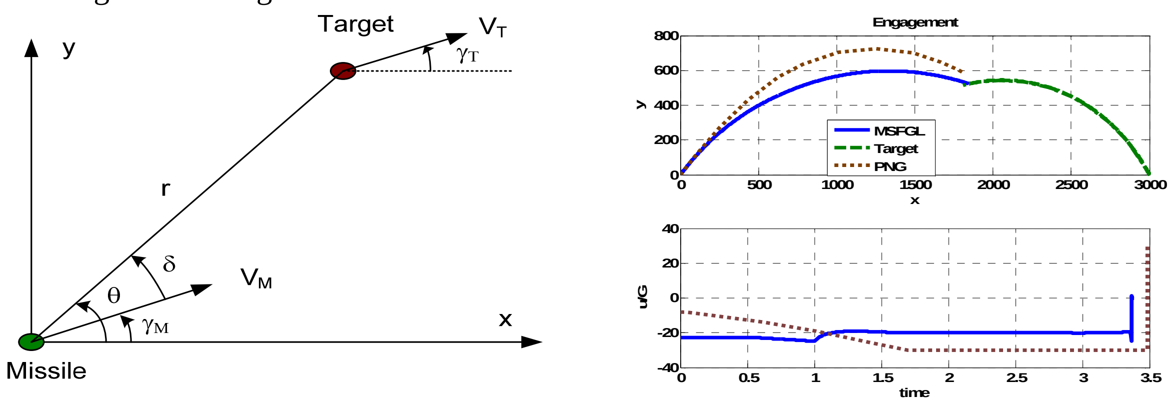

Figure 2. Interception geometry and time response

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