

## FUZZY LOGIC CONTROL AND 3D SIMULATION OF ROAD VEHICLE

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**Abstract:** Based on multidisciplinary nature and complexity of vehicle system, the design, control and development of vehicle system, generally depends on cutting edge technologies, thus this is a relatively time consuming and costly exercise. A very effective solution would be the development of a vehicle model, to simulate the system design prior to the practical implementation. This paper describes the design and development of a general vehicle model and computer simulations that are carried out by using Matlab/Simulink with 3D Virtual Reality output. Virtual Reality Markup Language (VRML) is the current preferred language in creating 3D virtual reality output and is supported by a number of CAD software's. The main objective in this paper is to establish a simulation model of vehicle system controlled by a Fuzzy Logic Controller, which is designed to emphasize quantifiable issues of vehicle such as: trajectory tracking and parking from any arbitrary position.

**Key words:** CAD; Fuzzy; Logic; Virtual; Simulink

### 1. INTRODUCTION

The objective of this paper is modelling and simulations of road vehicle system. In this paper, the modelling and simulation of a general vehicle system have been carried out using Matlab/Simulink as the simulation platform. The idea is to design and develop a general simulation platform to facilitate controller design and hardware configurations. The simulation output is represented by 3D model in Virtual Reality environment for more effective visualization. Besides that, Virtual Reality provides a new way for integrated multi-sensor simulation under a united environment (A. De Luca, 1998).

### 2. VEHICLE DRIVE MODEL

Vehicle drive system is a non-holonomic system [3, 5], where the number of control variables is less than the number of output variables. In this case, there are two control variables such as; the steering angle  $\phi$  of front wheels and vehicle body velocity  $v$ , and three output variables; the vehicle motions  $\dot{x}$ ,  $\dot{y}$  and  $\dot{\theta}$ . The generalized coordinates are  $q = (x, y, \theta, \phi)$ , where  $(x, y)$  are the Cartesian coordinates of  $B$  - mid point (Figure 1) of the rear wheels axle,  $\theta$  - measures the orientation of the car body with respect to the  $x$  axis.

The system is subject to two non-holonomic constraints, one for each wheel axis:

$$\dot{x} \cdot \sin(\theta) - \dot{y} \cdot \cos(\theta) = 0 \quad (1)$$

$$\dot{x}_A \cdot \sin(\theta + \phi) - \dot{y}_A \cdot \cos(\theta + \phi) = 0 \quad (2)$$

By using the rigid-body constraint:

$$x_A = x + b \cdot \cos(\theta) \quad (3)$$

$$y_A = y + b \cdot \sin(\theta) \quad (4)$$

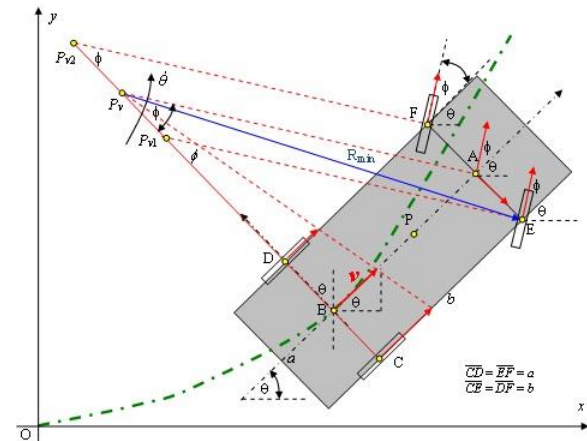


Fig. 1. Kinematics analysis of vehicle model

The first kinematic constraint (1) becomes:

$$\dot{x} \cdot \sin(\theta + \phi) - \dot{y} \cdot \cos(\theta + \phi) - b \cdot \dot{\theta} \cdot \cos(\phi) = 0 \quad (5)$$

Knowing that velocity of point B is:

$$v_B = \dot{x} \cdot \cos(\theta) + \dot{y} \cdot \sin(\theta) \quad (6)$$

Now constraint equations (1) and (2) can be written in matrix form:

$$C(q) \cdot \dot{q} = 0 \quad (7)$$

where:  $\dot{q} = [\dot{x} \quad \dot{y} \quad \dot{\theta} \quad \dot{\phi}]^T$  are generalized velocities?

$$C(q) = \begin{bmatrix} \sin(\theta + \phi) & -\cos(\theta + \phi) & -b \cos(\phi) & 0 \\ \sin(\theta) & -\cos(\theta) & 0 & 0 \end{bmatrix},$$

represent Pfaffians constraints matrix (A. Shala, 2004).

Solutions of equation (7) represent vehicle inverse kinematics.

From the Figure 1, can be derived the following relation:

$$v_B = v = \frac{b}{2 \tan(\phi)} \cdot \dot{\theta} \Rightarrow \dot{\theta} = \frac{v}{2b} \tan(\phi) \quad (8)$$

The design and 3D modelling are carried out by using Autodesk 3ds Max, which allows the 3D model to be exported in VRML (.wrl) format. VRML is the language for describing multi-participant interactive simulations – virtual worlds networked via the global Internet and Hyper-Linked with the World Wide Web”, quoted from Web3D Consortium. The model is exported in VRML format in order to be inserted into Matlab Virtual Reality environment for simulations.

### 3. FUZZY LOGIC CONTROLLER

Fuzzy Logic Controller (FLC), type Sugeno is used for Control and Simulation of vehicle model during parking of vehicle from any arbitrary point to the parking lot (Roger Jang, 2004).

Inputs in FLC (Figure 2) are:

- Distance of vehicle from parking lot.
- Maximal steering angle, if distance is far 'Mphifar' and
- Maximal steering angle, if distance is near 'Mphinear'.

Output from FLC is required for steering angle  $\phi$  of front wheels; this means that vehicle moves straight to the parking. Only two rules are required:

If (distance is near) then (output is  $\phi_1$ )

If (distance is far) then (output is  $\phi_2$ )

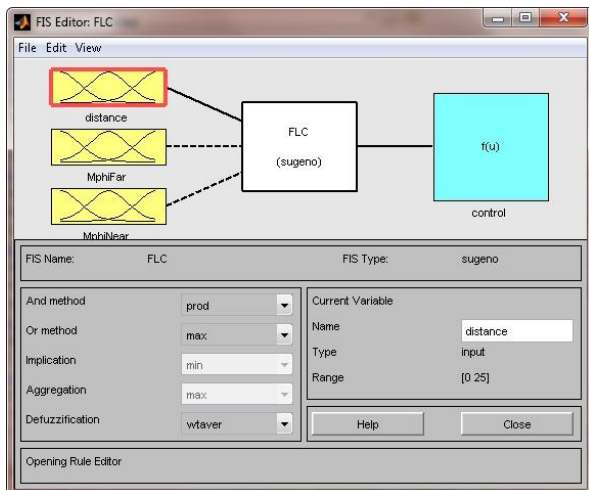


Fig. 2. Fuzzy Logic Controller, type Sugeno

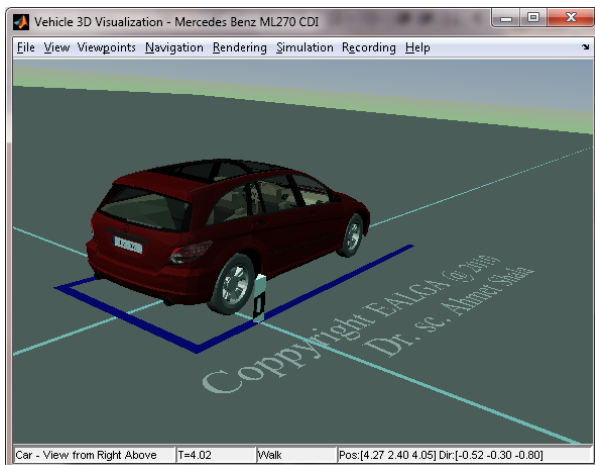


Fig. 3. Vehicle visualizations, Matlab/3D Simulink

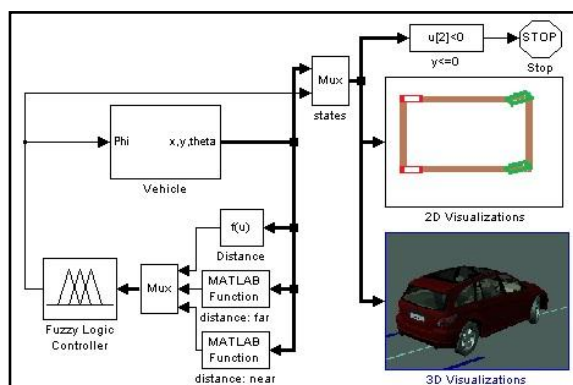


Fig. 4. Control scheme of vehicle simulation using FLC

Vehicle visualization is realised in 2D and 3D visualizations as is shown in Figure 3.

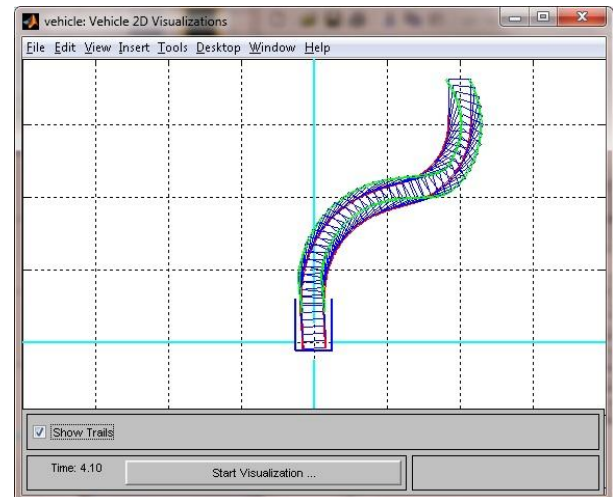


Fig. 5. Vehicle visualizations 2D view

Vehicle simulation and visualizations need three main VRML files: Vehicle Body VRML file, Road vehicle VRML file, Scene vehicle VRML file.

### 4. CONCLUSIONS

In this paper the modelling and simulation of a vehicle system has been developed. After setting the model requirements, the CAD model has been created using *Autodesk 3ds Max 2010*. Later on the CAD model is exported in the VRML format for Virtual Reality for representation. The mathematical model of vehicle is derived, in order to develop a Simulink model in Matlab for simulations. The simulation is linked together with the Virtual Reality model to complete a 3D simulation on the vehicle system.

Fuzzy Logic Controller works well for parking of the vehicle from any arbitrary position to the parking place (see Figure 3 and Figure 5).

As the first phase of the overall project for development and simulation of a general vehicle system, this paper established the fundamental simulation model for the future work. Additional important issue will be the usage of higher controllers such is Fuzzy-Neural Controllers for the vehicle system. But, prior to this, the feedback system in the Virtual Reality environment has to be developed. The interactive environment is needed, in order to simulate the control system. With the above mentioned components, a complete package for vehicle system simulation will be developed.

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