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Vehicle Impact Prevention at U-turns through Steering Angle Estimation Using Fuzzy Logics

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Abstract

In this research paper RetroU, an intelligent transport system is proposed. It is a two piece automated system which offers to prevent collision of vehicles with road medians / dividers while taking a U-turn; thereby reducing accidents and traffic congestions. The vehicle's B and C pillar regions are often blind spots for the vehicle drivers, mainly for cars and buses, thereby allowing 'vehicle–median collision' to be highly plausible. Moreover, there is an increasing chance of bottlenecks in traffic due to improper flow of traffic at U-turns. To prevent such incidents, this built-in system assists the driver in easy navigation at U-turn using Fuzzy logics. The steering angle and turn radius calculated are fed back to the driving wheel to perform a smooth turn. Radar sensors placed in the road medians compute and communicate the rate of rotation of the vehicle to the driving wheel, when the driver wishes to go for a turn.

This system is highly adaptable for countries such as India, Nepal and South Africa, where the feasibility of implementing, rather fruitful mechanism such as 'Michigan left' and 'Median turn thru' is not possible due to lack of space and resources.

Keywords: B and C pillar collisions, Blind spots, Fuzzy Logic, RADAR sensors, RetroU, Road medians, U-turn

1. Introduction

Bottlenecks at U-turns are prominent causes for traffic congestions. Besides, drivers have to be extremely cautious as the turns demand their complete attention. It is a tedious task to be constantly vigilant about shoulder checks while moving forward. Situations are even worse when the vehicle is long enough, extending into B and C pillars.

RetroU, the proposed two piece system consists of static and moving components. The static part is fixed inside the median annexure to detect and guide vehicles, while the moving part coupled with the driving wheel receives constant feedback from the stationary part.

The static part of RetroU can be briefed as a system comprising of low cost FM-CW radar to identify the state of external environment, stationary or in motion, up to 5m [1]. This section of RetroU is responsible for the estimation of the turn radius.

The moving part incorporated the vehicle has the dimensions of the vehicle's body, such as the wheelbase, front track etc which are communicated to the static part of RetroU in the road median. The fuzzy logic implemented is responsible for the decision making. Any deviant response to the feedback provided to the moving parts would force the static part to recalibrate and the cycle continues. This allows the driver to alter, if needed, the course of the turn radius for undetected situations such as avoiding potholes.

Practices such as Michigan left [2] are futile as they require more space and pre-planned design of roads; furthermore, they come with the task of comprehending the drivers with its utility, which is a herculean task. Hence RetroU mechanism caters to the needs as a low cost and versatile substitute.

2. Mechanism of Retro U

Phase I–Trigger Phase

When vehicles equipped with RetroU approach the vicinity of the U-turn, the driver signals to take a turn by switching on the Indicator, transmitting the vehicle descriptions to the static part (red square marked with 1 in Fig. 1). It is not mandatory for the driver to signal. While otherwise, RetroU waits for the steering wheel to cross the threshold set, once it crosses the limit it triggers the moving part to deliver its dimensions to the static part. The receptor in the static part actively scans the vehicles for the triggers mentioned above.

The static part communicates to its opposite RetroU (red square marked with 3 in Fig. 1) about the vehicle and its dimensions to alert the vehicles passing in the opposite lane. In this case, alerts the blue car (numbered 5 in Fig.1).

FM–CW Radar is incorporated in the static part which identifies the vehicle approaching at a distance R. The echo reflects after time duration of 2R/c. Hence the wavelengths are 2R/c.

$$T=2R/c$$

R(Distance between target and radar)=$\{cf_b\}/ 4f_m\Delta f$

The wavelength being $1/f_m$, where f_m is the modulation frequency, for a triangular waveform. Δf is the radar carrier range. The beat frequency is identified by subtracting the radar output of no target with that of the one to target.

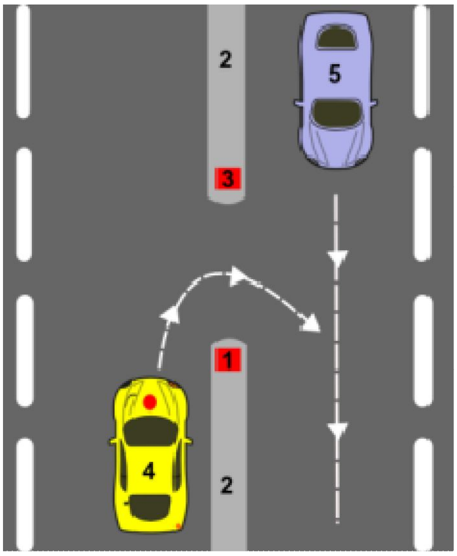

Fig. 1: Pictorial of Car (marked 4) trying to take a U-turn from the guide path trace (curved dotted line) from the stationary part fixed to road median annexure (marked 1).

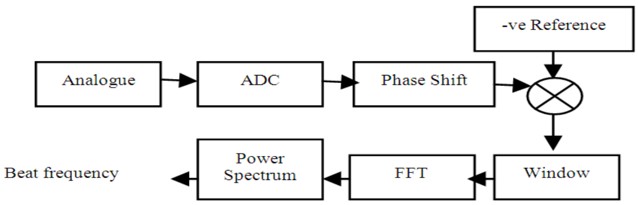

Fig. 2: Radar signal processing block diagram.

Phase II–Turn Radius Calibration

The majority of the vehicles mechanizes under Ackerman Steering conditions, reduce the slipfree. In the phases I, dimensions such as wheel base (l), front axle track (w), the distance between the rear axis and the center (a) are transmitted to the static part. This allows the static part to calibrate the turn radius, using the following formula [3]. It has to be noted that the rear axle track does not contribute to the turn radius. GPS tracker placed in the vehicle at positions either A or B (as in Fig. 2) estimates the Rmin used for computation of space occupied by the vehicle.

$$R\ (\text{turn radius}) = \sqrt{\{a^2 + l^2 \cot^2 \delta\}}$$

Vehicles draw two concurrent curves where the wheel towards the center makes larger angles than the wheel away from the center. A circle formed with the inner wheel marks a minimum turn radius (Rmin); while the outer wheel along with the overhang distance makes a maximum turn radius (Rmax). The overhang distance (g) is the extra distance between the frontal axis and the frontal edge of the car. Rmax formed depicts the maximum area utilized for the car to turn.

$$R_{max} = \sqrt{\{(R_{min} + w)^2 + (l + g)^2\}}$$

Where l=wheel base; w=front axle track; a=distance between center and rear axis; g=over hang distance, Rmin is OD distance as in Fig. 2.

In cases where the distance between the two road median annexures is less, Rmax thus calculated is deducted from the distance between the two static and opposite RetroU and allowing the other RetroU (red square marked with 3 in Fig. 1) to allow other vehicle, whose turn radius is feasible for the given distance, to go for a U-turn, smoothening the navigation even more.

The ideal space a vehicle would be utilized to take a turn would be the difference between sectored area formed with Rmax and Rmin.

$$\Delta R = R_{max} - R_{min}$$

$$\Delta R = \sqrt{\{(R_{min} + w)^2 + (l + g)^2\}} - R_{min}$$

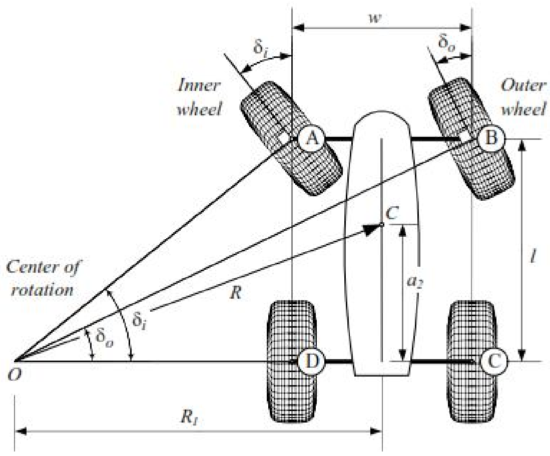

Fig. 2: Geometric vehicle model with its axis passing through the real axle and frontal wheels meet at the center of rotation–O.

Phase III–Going for the turn

The turn angle, calibrated in the static part of the RetroU using the formulas used for turn radius in the phase II, is fed to the steering controller in the vehicle as a reference signal. Now that the target trajectory is acquired the fuzzy logic is ready to be implemented. The signal is fed through PID controller to obtain a PWM signal. Torque using DC motor is derived through the PWM signal passing through DC motor to guide the steering wheel [2]. Steering position is fed back to the PID Controller through a feedback circuit.

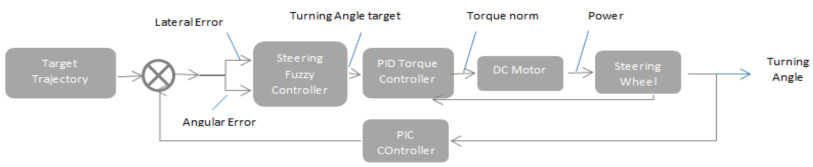

Fig. 3: Block Diagram schematic–Fuzzy implementation Steering Wheel drive.

The hybrid architecture implementation of both fuzzy controllers and PID controllers deals with non-linearity. Non-Linearity is dealt by Fuzzy Controller whereas PID deals with actual movement of steering wheel making the calls or decisions as humanly possible.

The vehicle positions are obtained from the GPS sensors which are 1 cm accurate and a constant feedback is compared with the received reference trajectory eliminating the lateral and angular errors. Simultaneous fuzzification and interference provides wheel angle which is further transformed for use of steering actuator through defuzzification. Implication methods are applied before aggregating the fuzzy sets as outputs. Fuzzy membership functions define fuzzy partitions. Each Fuzzy linguistic variable has one partition.

Sensor discrete values are converted into membership degrees (n) for fuzzy partitions of linguistic variables [4].

$$\mu \text{ Partition } \_\ n\ (\ )\ x \in [0,1]\ x \in X$$

Error possibilities are eliminated to mimic a human capability in driving and decision making. Basic understandings of the maneuvering the vehicle can be understood through the following fuzzy variables are given as rules for controller [3]. Rule based depending on vehicle behaviour are as follows:

Rule	IF	Angular_Error		THEN	Steering
R1		IF	*Left*	THEN	*Right*
R2		IF	*Right*	THEN	*Left*
R3	I	F	*zero*	THEN	*Maintain*

The boldface words are fuzzy variables, whereas the lingual labels are italicized.

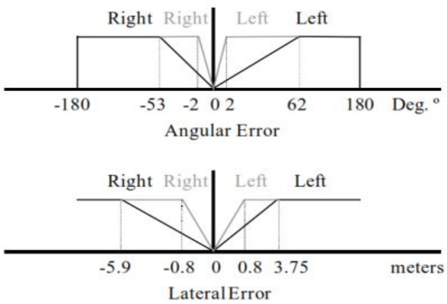

Fig. 4. Angular and Lateral error membership functions for fuzzification

Fuzzy partitions of linguistic variables for Steering are Right, Left and Maintain.

3. Flow chart

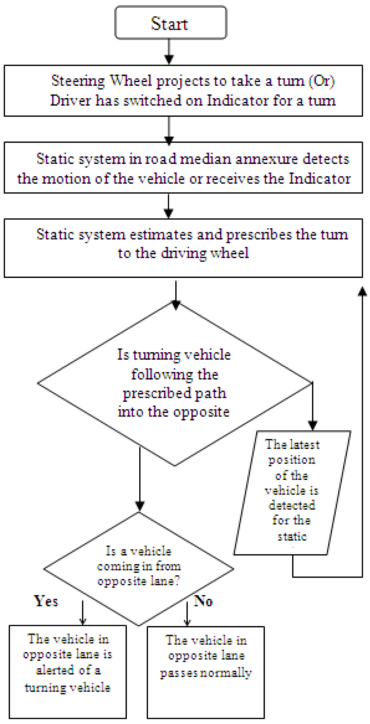

Fig. 5: Flow chart working for RetroU algorithm.

4. Conclusion

Smooth and hustle free traffic flow could be ensured in countries with limited resource allocations for transportation using RetroU. Implementation of fuzzy logics and feedback gives the driver the experience of being mimicked. The low cost sensors and implementations are highly adaptive, thus making RetroU considerably useful in many scenarios.

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