



Comprehensive evaluation method for performance of unmanned robot applied to automotive test using fuzzy logic and evidence theory and FNN

Gang Chen^{a,*}, Weigong Zhang^b

^a School of Mechanical Engineering, Nanjing University of Science and Technology, Nanjing, China

^b School of Instrument Science and Engineering, Southeast University, Nanjing, China

ARTICLE INFO

Article history:

Received 20 June 2017

Received in revised form 28 January 2018

Accepted 26 February 2018

Available online xxx

Keywords:

Unmanned robot

Automotive test

Performance evaluation

Fuzzy logic

Evidence theory

Fuzzy neural network

ABSTRACT

In order to obtain reliable and exact evaluation, a new comprehensive evaluation method for performance of an unmanned robot applied to automotive test (URAT) using fuzzy logic, evidence theory and fuzzy neural network (FNN) is presented in this paper. Throttle repeatability, speed tracking accuracy, speed repeatability, driving shock degree are used as the system evaluation index. The subjective evaluation results with various expressions are quantified using fuzzy logic. The group decision making with quantified subjective evaluation results from various drivers is combined through evidence theory. The objective evaluation indexes measured by instrumentation and the corresponding combined subjective evaluation are self-learned and trained with FNN. The comprehensive performance evaluation system of the URAT is established. Finally, real vehicle experiments are conducted. The effectiveness of the presented method for the URAT is experimentally verified.

© 2018 Elsevier B.V. All rights reserved.

1. Introduction

With the development of the automobile industry, the performance requirements of automotive are increasing. It is necessary for the improvement of vehicle performance to conduct a large number of automotive tests. It takes much time for automotive test [1]. It has the characteristics of time saving, cost saving and safety that conducts automotive test on chassis dynamometer. In the automotive sector, an accurate and repeatable procedure for automotive test is needed. For many automobile tests, such as emission durability test, fuel economy test, the driving behavior of a human driver is one of the sources of statistical and systematic errors. The different driving skills, and physiological and psychological factors of human driver affect the results of automotive test. The test environment is very poor and dangerous, so that it is suitable for a robot to conduct automotive test [2,3]. URAT is a robot which can be equipped in a vehicle cab without any modification [4,5]. It can be used to conduct autonomous driving replace of a human driver. Because the URAT can be directly installed in the different vehicle cab and the vehicle is not needed to be modified, it can be applied to emission

durability test, vehicle performance test, vehicle noise test, high and low temperature environment test, vehicle road test, vehicle bench test, autonomous vehicle, intelligent vehicles, and other fields [6,7].

The performance evaluation method of the URAT is the basis of the robot control and design, which is a key technology of the URAT development. Noguchi S, et al. propose an evaluation method for measuring the driving capability of a robotic driver using regression analysis, however the method does not concern subjective evaluation of various drivers [8]. Jeong S, et al. propose a self-balancing personal mobility vehicle with a hybrid mechanism and discuss its features from the perspectives of power-assist driving performance and a rider's evaluation, however the method does not concern the vagueness and uncertainty of various drivers [9]. Evaluation method for the performance of the URAT includes subjective evaluation and objective evaluation. Chen Gang, et al. designs an evaluation model for vehicle shift quality based on evidence theory and fuzzy neural network [10]. However, the model does not consider the uncertainty and different expression ways of subjective evaluation from various drivers. Chen Gang, et al. designs an approach to vehicle shift quality subjective evaluation based on fuzzy logic and evidence theory [11].

* Corresponding author.

E-mail address: gang0418@163.com (G. Chen).

However, the approach does not take into account objective evaluation from instrumentation. It is good for fuzzy logic to express subjective evaluation from various drivers [12]. The evidence reasoning using evidence theory has a good consistency with human's reasoning [13,14]. Besides, fuzzy neural network (FNN) has not only self-learning ability of objective indexes but language reasoning ability [15,16].

In this paper, a novel evaluation method for performance of the URAT based on fuzzy logic, evidence theory and FNN is presented. Throttle repeatability, speed tracking accuracy, speed repeatability, driving shock degree are used as the system evaluation index. The subjective evaluation results with various expression ways are quantified using fuzzy logic. Besides, the quantified subjective evaluation results from various drivers are combined by evidence theory. Moreover, the objective evaluation indexes measured by instrumentation and the corresponding subjective evaluation are self-learned and trained by FNN. The comprehensive performance evaluation system of the URAT is established. Real vehicle experiments are conducted. Experimental results show the effectiveness of the presented method.

2. Evaluation indexes

Throttle repeatability, speed tracking accuracy, speed repeatability, shock degree of driving are used as the evaluation index of the URAT performance.

2.1. Throttle repeatability

The sampling data of throttle pedal opening degree at the time t_i is defined as $f(t_i)$. The repeatability of throttle pedal is obtained by regression analysis method.

2.2. Speed tracking accuracy

Due to that root mean square (RMS) of speed error has large errors weights, and the margin of error can not be offset, it is able to

characterize the global error.

$$V_{RMS} = \sqrt{\frac{\sum_{i=1}^K (V_{act}(t_i) - V_{set}(t_i))^2}{K}} \quad (1)$$

Where, $V_{act}(t_i)$ is actual speed of chassis dynamometer, $V_{set}(t_i)$ is set speed of chassis dynamometer, t_i is sampling time, K is the total number of automotive test data samples. When actual measured speed can accurately track the set speed, $V_{RMS} = 0$.

2.3. Speed repeatability

The control performance of throttle is characterized by the motion speed of the throttle pedal. Assume that the engine speed at the time t_i is $n_e(t_i)$, and in the next sampling time the engine speed at the time $t_i + \Delta t$ is $n_e(t_i + \Delta t)$. Where, Δt is the sampling period. The engine speed error Δn_{ei} at the time t_i

$$\Delta n_{ei} = n_e(t_i + \Delta t) - n_e(t_i) \quad (2)$$

In the whole test condition, the average deviation of the engine speed

$$\bar{n}_e = \frac{1}{K} \sum_{i=1}^K \Delta n_{ei} \quad (3)$$

The residual variance of the engine speed

$$S_v^2 = \frac{1}{K} \sum_{i=1}^K (\Delta n_{ei} - \bar{n}_e)^2 \quad (4)$$

If the motion of the throttle pedal is steady in the whole test condition, $S_v = 0$. When S_v is larger, the motion of throttle pedal is less smooth.

2.4. Driving shock degree

Driving shock degree j is the change rate of the longitudinal acceleration during the process of driving. In the process of the shift, the driving shock degree

$$j = \frac{d^2 u}{dt^2} = \frac{r d^2 \omega_2}{i_0 dt^2} = \frac{r}{[i_g^2 (I_e + I_1 + I_2) i_0]} \frac{d(T_e i_g)}{dt} \quad (5)$$

Where, ω_2 is the angular velocity of vehicle transmission output shaft. I_e is the moment inertia of engine and clutch active disc. I_1 is the equivalent moment inertia of rigid connection after converting to vehicle transmission input shaft. I_2 is the equivalent moment inertia of total vehicle quality and tires after converting to vehicle transmission input shaft.

3. Evaluation method

The multi-index comprehensive evaluation method combined with subjective evaluation and objective evaluation using fuzzy logic, evidence theory and FNN is presented.

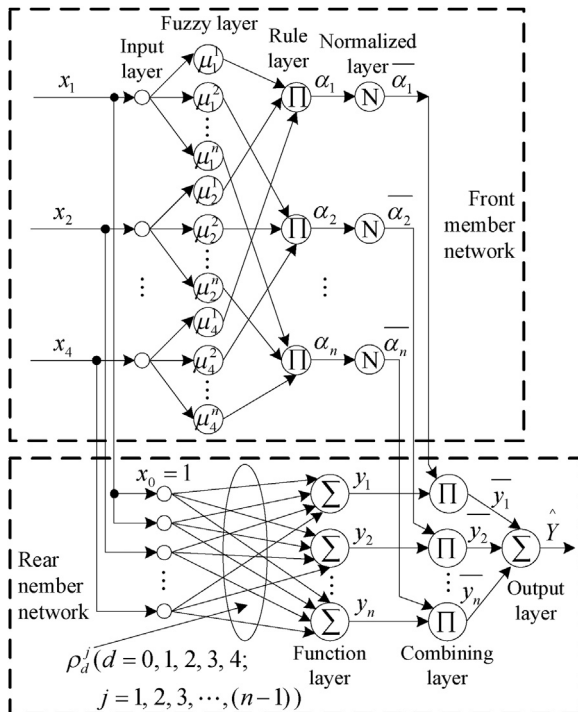


Fig. 1. The FNN structure.

Table 1
The definition of human driver' expression.

u_{ij}	1	2	3	4	5
Excellent	1	0.75	0	0	0
Good	0.25	1	0.75	0	0
General	0	0.5	1	0.5	0
Bad	0	0	0.75	1	0.25
Poor	0	0	0	0.5	1

Download English Version:

<https://daneshyari.com/en/article/6923746>

Download Persian Version:

<https://daneshyari.com/article/6923746>

[Daneshyari.com](https://daneshyari.com)