Fault Classification in Vehicle Power Transmission using Machine Learning

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Abstract – The work describes the application of machine learning (ML) to the categorization and diagnosis of vehicle faults in the power transmission system. For each failure characteristic condition, a machine learning algorithm may be employed to categorize their separate diagnostic elements. The use of acoustic sensors can be used to create a real-time detection approach for vehicle engines and transmission systems. Previously, it was contacting drivers or obscuring services based on vehicle maintenance and driving safety degree under internet of vehicle (IoV) needs. The car's variable acoustic signals are captured and categorised utilising fuzzy logic controllers through the data acquisition device (DAQ) in this manner (FLC). Further, the results are optimized using Particle Swarm Optimization (PSO) technique. While previous systems used 15 fault conditions, we have just used 8 conditions to obtain results.

Keywords — Machine learning, Transmission system, Particle swarm optimization, Fuzzy logic.

I. INTRODUCTION

In the context of machine status monitoring, data-driven approaches are methodologies that are increasingly being employed for anomaly and defect detection. For a number of reasons, such as the rarity of anomalies or a lack of data to detect fault states, high integrity systems could not always use the standard learning classification technique. Finding faults is among the most critical components of quality assurance. Fault detection is crucial for lowering the time and cost of software design. Regardless of the fact that software engineering offers a variety of detecting methodologies, an uniform software fault detection technique is necessary.

An automobile's transmission system is critical to vehicle handling, manoeuvrability, performance, and ride comfort. Vehicle control is affected by the force that occurs between both the roadways and the tires. The passenger's perception of vehicle motion affects ride comfort.

Various types of transmission systems, such as passive, semiactive, and active transmission systems, are used to adjust ride comfort and vehicle handling. For decades, most automotive manufacturers have used a passive transmission system that comprises of a coil spring or a leaf spring in tandem with a viscous damper. The primary gain of a lively transmission is the associative variation capability in which the transmission traits may be adjusted at the same time as riding to fit with the profile of the street being traversed. To avert tragedy, a vehicle's power transmission system should be monitored closely by diagnostic system and analytics that can immediately determine the kind of failure and alert the driver at the early stage of the problem. So far, a range of defect detection and pre-judgment systems for use in the production line have been presented, based on different sensors and amounts of sensing data. These sensor data will be combined with classification methods, then machine learning will be used. One of the significant disadvantages is that at the time of engine beginning, only valid (nominal) data is available for training. By modelling normal data and identifying irregularities using a distance measure and a threshold, novelty detection provides a solution to this challenge. Because transmission systems are designed to not fail, obtaining enough data for machine learning algorithms to be trained, validated, and tested is difficult. We will suggest a concept for extending machine learning skills beyond fault detection to fault classification with the limitation that only nominal data is available for training in the next sections.

II. RELATED WORK

Rajamani and Hedrick (1995) [1] evolved an adaptive observer for identity of the sprung mass of the automobile. The mechanics of the hydraulic actuator are examined in a realistic form of the transmission mechanism. The viewer is used to accommodate to electrohydraulic dry friction, as well as spring stiffness, viscous damping, and hydraulic bulk modulus. Yoshimura et al [2] (2001) evolved Variable Structure System (VSS) observer for the lively transmission device. SMC is used as a manipulate scheme and the lively manipulate pressure is received via way of means of the usage of a pneumatic actuator.[3] Road profile is expected via way of means of the usage of a simplified VSS observer.

The proposed lively transmission device indicates a development in vibration isolation of the automobile frame than LQ manipulate. Adizul et al (2005) [4] carried out Proportional Integral Sliding Mode Control (PISMC) method with observer layout for a lively transmission device. Simulation outcomes reveal that PISMC with disturbance observer offers higher overall performance than Linear Quadratic Regulator (LQR) controller. Using Lyapunov balance theory, its miles proven that the estimation blunders is bounded stable. Dixit and Buckner (2005) [5] carried out Sliding Mode Observation and Control (SMOC) method to a semi lively automobile transmission device the usage of version reference approach [6]. Sliding Mode Observer (SMO) is evolved to estimate the unmeasured country variables that require handiest transmission deflection as a measured input. Simulation outcomes reveal that PISMC with disturbance observer offers higher overall performance than Linear Quadratic Regulator (LQR) controller [7]. The street profile is expected via way of means of the usage of an observer.

Cheng et al (2010) [8] designed a full-automobile lively transmission controller with a discounted order observer for cars in order to enhance journey consolation and decrease the transmission deflection. Three forms of street profiles, a bump street, a random white noise and an energy spectral density street profile are used within the study [9]. Simulations reveal that the proposed FSMC can offer the high-quality journey consolation and the least transmission deflection below these kind of street profiles. [10]

Active transmission structures were extensively studied over the past 3 decades. Various manage techniques consisting of gold standard state-feedback, returned stepping method, fuzzy methods were proposed within side the beyond to manipulate the lively transmission device [11].

III. FUZZY LOGIC CONTROLLER

Ting et al (1995) [12] evolved a fuzzy manipulate scheme for energetic transmission manipulate device on the premise of decreased order version evaluation and SMC principle. Fuzzy manipulate regulations are built on self-tuning method in preference to human expertise. Set of regulations are integrated because the research desk of microcomputer for realistic implementation. The robustness of the controller is likewise discerned. Chattering phenomenon inherent from the SMC is removed because of the fuzziness of the FLC. Simulation effects display quality overall performance below perturbed conditions. Barr and Ray (1996) [13] designed and simulated a FLC for an energetic transmission device. The overall performance is in comparison with LQG managed energetic and passive transmission.

Neither LQG nor FLC scheme confirmed a development in street handling. But trip consolation is advanced in FLC primarily based on totally energetic transmission. Yoshimura (1996) [14] evolved an energetic transmission device based on the usage of fuzzy logic. The energetic manipulate is decided such that the passenger trip consolation is minimized below the constraint of the transmission deflection and tyre deflection.

Fuzzy Sliding mode control

Huang and Lin (2003) [15] proposed a unique Adaptive Fuzzy Sliding Mode Controller (AFSMC) to manipulate an energetic hydraulic transmission system. This manages approach establishes the bushy policies with the aid of using non-stop on-line mastering as opposed to trial and mistakes manner. It simplifies the implementation of FLC.

The experimental results showed that this AFSMC reduced the sprung mass functional fluctuation intensity significantly. In addition, the manage voltage is clean and converging velocity of the variation set of rules is quick. Huang and Chen (2006) [16] advanced a useful approximation primarily based totally adaptive sliding controller with fuzzy repayment to manipulate sector vehicle hydraulic energetic transmission. Literature evaluates famous that maximum of the proposed manipulate techniques examined on simulated fashions and handiest few effects are to be had with experiments on actual vehicle [17-18]. Optimal manipulate has been utilized by maximum of the researchers. Fuzzy good judgment is typically used on top of things method and the club capabilities were decided with the aid of using trial-and-mistakes method [19]. Hence a technique of tuning FLC parameters is given significance. SMC and FSMC were mentioned in a few papers for energetic transmissions manipulate to make certain robustness [20].

IV. PROPOSED METHOD

Image Processing for Defect Detection To cope with street defects, many devices mastering and photograph processing technology had been used to offer the first-rate centers to the drivers. Many of those programs are set up within side the automobile and locate the defects at the roads from a distance, which alert the motive force and limit the possibilities of accidents.

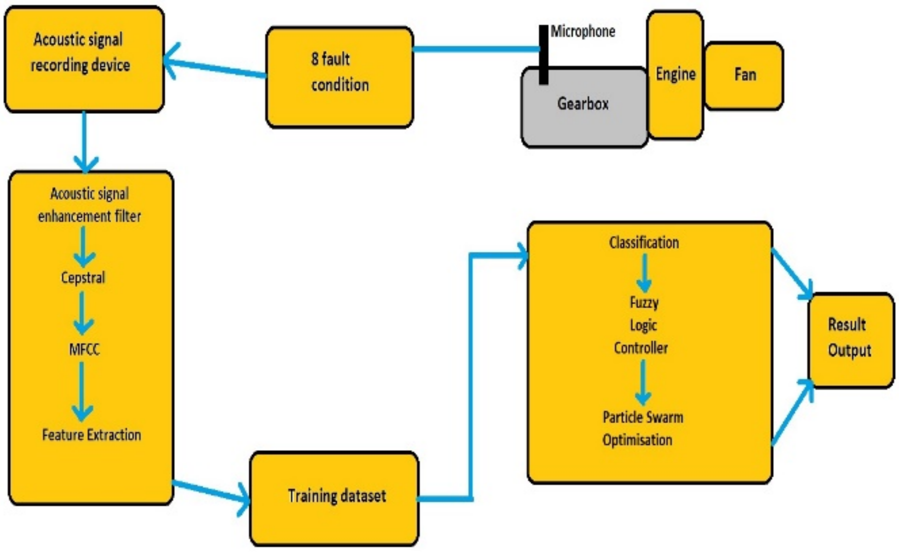

Fig 1. Overall System Model

Previous strategies of fault detection on street had been time-consuming. The most important problem which arises in the course of the disorder evaluation via device mastering and photograph processing is the presence of noise and the randomness within side the shapes of the defects. All the photograph primarily based totally structures have a few fundamental steps which are observed to make certain accurate detections, an outline of the photograph-primarily based totally detection gadget.

Various strategies of function extraction are carried out to the uncooked snap shots which lessen the dimensionality of the photograph and shop the computational time and resources. Some of the fundamental function extraction strategies are facet detection, noise and background, photograph segmentation, essential thing evaluation (PCA), and speeded-up strong features (SURF). For even superior strategies of extraction, optical flow, a histogram of orientated gradients, Histogram Chain Codes, and wavelet-primarily based totally strategies are used.

Proposed controller structure

FLC is used for disturbance rejection manage to lessen undesirable car's movement. Transmission bending and sprung mass pace are taken because the enter variables and actuator pressure because the controller's outcome. The scaling factors are GE, GV, and GU. RMS price of the frame acceleration is implemented because the overall performance index. GA/PSO set of rules tunes the dimensions factors, club capabilities and the manage policies of the FLC.

Fuzzy Logic Controller Vehicle transmission gadget could be very complex and relatively nonlinear. Transmission parameters will alternate whilst a car rides on numerous street conditions. Conventional manage techniques rely upon correct gadget version and unable to adjust to changing environmental circumstances. Genetic Algorithm (GA) are adaptive seek strategies primarily based totally on a "survival of the fittest" organic concept.

They can produce a green and strong method for optimization by attempting to locate an international minimum without a charge function as a by-product. Basically, GA includes 3 important stages: Selection, Crossover and Mutation. The programme that combines those three basic actions produces a new man or woman who is capable of outperforming their parents. This set of principles is repeated for many generations until it reaches people who are the solution to the problem. Due to its effectiveness in looking nonlinear, multi-dimensional seek spaces, GA is implemented to the tuning of the dimensions parameters, club capabilities and manage policies of the FLC to make sure most fulfilling manage overall performance at nominal operating conditions. The 51-bit binary GA-chromosome used to encode GAFLC is shown in Table 1.

Table 1. GA-chromosome used to encode GAFLC

Item	Size
Population size	30
No. of iterations	100
wmax	0.4
wmin	0.9
c1 & c2	2

Particle Swarm Optimization

Particle Swarm Optimization (PSO) is a population-based stochastic optimization approach invented in 1995 by two Britishers, who were inspired by the social behaviour of birds flocking or fish schooling. The right inertia weight w strikes the right mix among global and regional discoveries. Generally, the inertia weight w is calculated using the equation below

$$w = w \quad - ((w \quad - w) * t / T) \tag{1}$$

Simulation Results

The mathematical formalism of the effective transmission mechanism represented by formula is run on an emulator, as well as the proposed controller, is simulated. Fig 2 depicts the bump disruption for amplitudes between 10cm and 5cm. Bump feedback is a kind of input that has been used in the literature.

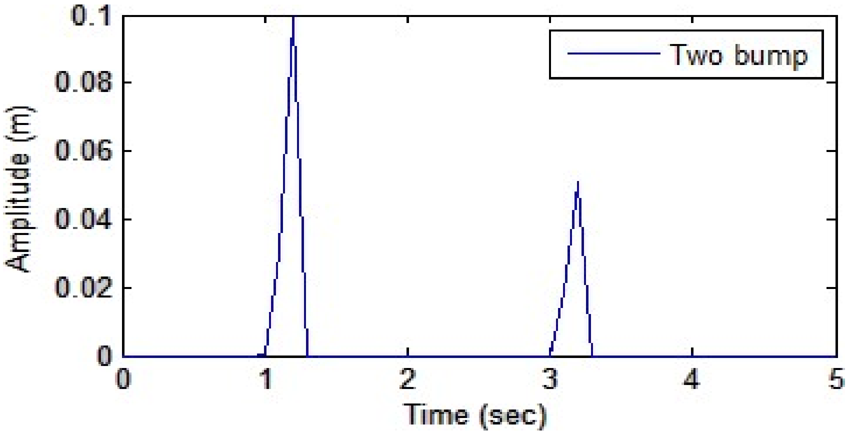

Fig 2. Bump Feedback

MATLAB and SIMULINK are used to run the simulations. To handle the fuzzy system, scaling wins, control rules, execute the simulation, review the results, and continually adjust the fuzzy system in pursuit of an optimal solutions, the tuning approach employs MATLAB M-files and methods. Fig 3 and 4 indicate membership features after GA and PSO tuning.

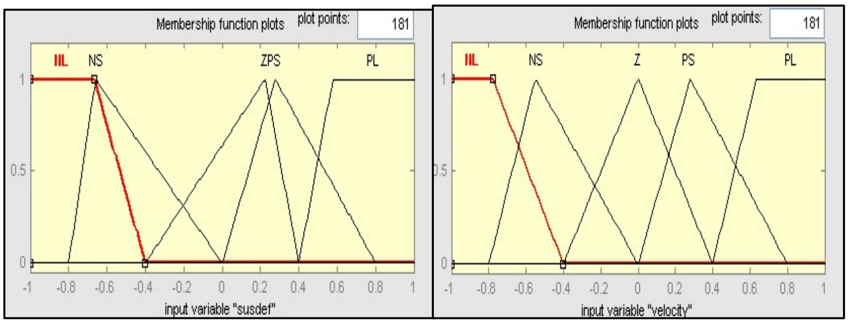

Fig 3. Membership features after GA tuning

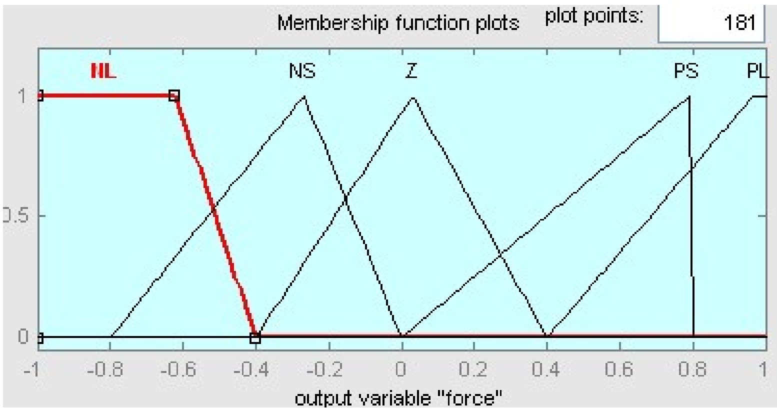

Fig 4. Membership features after PSO tuning

Optimized scale factors are
GE = 0.4136; GV =4.4334; GU =1.4488(GA) GE=0.1001;
GV=4.9813; GU=1.4962(PSO)

V. CONCLUSION

The performance of PSO algorithms for Fuzzy Logic control of an Active Transmission Mechanism and facts acquired from data processing strategies have been in compared in this paper. The use of Particle Swarm Optimization for optimising the results has proven to be very effective than the previous systems. While previous systems used 15 fault conditions for classification, we have achieved classification in just 8 fault conditions. The result graphs all have been explained in this paper. The simulation outcomes naturally display that the PSOFLC suspension system's trip consolation and a venue preservative capability have improved. When in comparison to with previous systems, PSO set of rules has a wide overall performance of convergence.

References

[1]. F.J. D'Amato and D.E. Viasallo, "Fuzzy Control for Active Transmissions," Journal of Mechatronics, Vol.10, pp. 897- 920, 2020.
[2]. D.Hrovart, "Application of optimal control to Dynamic advanced automotive transmission design," Transactions of ACME, Journal of Dynamic System, Measurement and Control, 115, pp. 328-342, 2020.
[3]. Alleyne, A. and J.K. Hedrick "Nonlinear Adaptive Control of Active Transmissions", IEEE Trans. Contr. Syst. Technol., Vol. 3, pp. 94-101, 2020.
[4]. Esmailzadeh, E. and H.D. Taghirad: "Active Vehicle Transmissions with Optimal State Feedback Control," J. Mech. Sci., pp. 1-18. 2020.
[5]. Lin, J.S. and I. Kanellakopoulos, "Nonlinear Design of Active Transmission," IEEE Contr. Syst. Mag., Vol. 17, p. 45-59., 2020
[6]. M.V.C. Rao and V. Prahalad: "A tunable fuzzy logic controller for vehicle-active transmission systems," Elsevier, Fuzzy sets and systems 85(1): pp. 11-21, 2020.
[7]. T. Yoshimura, A. Kume, M. Kurimoto and J. Hino: "Construction of an Active transmission system of a Quarter car model using the concept of Sliding mode control," Journal of Sound and Vibration 239(2), pp. 187-199, 2020
[8]. Yahaya Md. Sam, Johari H.S. Osman and M.R.A. Ghani, "A class of proportional –Integral sliding mode control with application to Active transmission," Elsevier, Systems & control letters, 51, pp. 217-223, 2020
[9]. Shiuh-Jer Huang and Wei-Cheng Lin, "Adaptive Fuzzy Controller with Sliding Surface for Vehicle Transmission Control.," IEEE transactions on fuzzy systems, 11(4), pp. 550-559, 2020.
[10]. Eberhart, R. C., and Shi, Y. Particle swarm optimization: developments, applications and resources. *Proc. Congress on Evolutionary*, Seoul, Korea. Piscataway, NJ: IEEE Service Center. pp. 81-86, 2020.
[11]. Y. Lei, F. Jia, J. Lin, S. Xing, and S. X. Ding, "An intelligent fault diagnosis method using unsupervised feature learning towards mechanical big data," *IEEE Trans. Industr. Electron.*, vol. 63, no. 5, pp. 3137-3147, May. 2016.
[12]. J. D. Wu, and M. R. Bai "DSP implementation of active noise control in engine exhaust system," *J. J. Appl. Phys*., vol. 39, pp. 4982-4986, Aug. 2000.
[13]. R. T, H. Ahmadi, F. Sassani, and G. Dumont, "Informative wavelet algorithm in diesel engine diagnosis," *Proceedings of the 2002 IEEE International Symposium on Intelligent Control,* Vancouver, Canada., Dec. 361-366, 2002.
[14]. J. Lin, "Feature extraction of machine sound using wavelet and its application in fault diagnosis," *NDT&E International.*, vol. 34. no. 1, pp. 25-30, Jan. 2001.
[15]. M. H. Weatherspoon, and D. Langoni, "Accurate and efficient modeling of FET cold noise sources using ANNs," *IEEE. Trans*., vol. 57, no. 2, pp. 432-437, Jan. 2008.
[16]. H. Anandakumar and K. Umamaheswari, "Supervised machine learning techniques in cognitive radio networks during cooperative spectrum handovers," Cluster Computing, vol. 20, no. 2, pp. 1505–1515, Mar. 2017.
[17]. H. Anandakumar and K. Umamaheswari, "A bio-inspired swarm intelligence technique for social aware cognitive radio handovers," Computers & Electrical Engineering, vol. 71, pp. 925–937, Oct. 2018. doi:10.1016/j.compeleceng.2017.09.016
[18]. R. Muralishankar, and A. Sangwan, "Theoretical complex cepstrum of DCT and warped DCT filters," *IEEE. Sign. Process*., vol. 14, no. 5, pp. 367-370, May. 2007.
[19]. H. K. Kim, and R. C. Rose, "Cepstrum-domain model combination based on decomposition of speech and noise using MMSE-LSA for ASR in noisy environments," *IEEE. Trans. Audio Speech*, vol. 17 no. 4, pp. 704-713, May. 2009.
[20]. L. Shi, I. Ahmad, Y. He, and K. Chang, "Hidden Markov model based drone sound recognition using MFCC technique in practical noisy environments," *J. Commun. Net.*, vol. 20, no. 5, pp. 509-518, Oct. 2018.