Review Article

A Finite-Time Speed and Direction Control for Four-Wheel Drive System

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Abstract

With the rapid use of the Four-Wheel Drive System (FWDS) worldwide, the necessity of having an adequate control system to control speed and direction in FWDS is extremely required. For this purpose, several control schemes are available in the literature to control the speed and direction in FWDS which should be fast convergence of the control, continuous control performance, and solving external disturbances. In latest years, finite-time controllers (FTC) have gained more consideration from many researchers in the control area, who have expressed applications in several procedures and systems. This research provides a major review of the FTC approaches via both input and output feedbacks for controlling FWDS.

Keywords: Finite-Time Controller, FTC, Four-Wheel Drive System, FWDS, Speed and Direction Control.

1. Introduction

The concern of the global warming issues for using fossil fuels is very high. The combustion engines in cars that use these traditional fossil fuels make major car manufacturers transfer to produce electrical vehicles (EV). EVs are considered clean and friendly to the environment. EV is required not just to operate on batteries but also is needed to be smart. Four-wheel drive systems (FWDS) are considered smart vehicles which include many complex controllers to drive them more efficiently and safely on the roads.

The major problems of FWDSs are the need for advanced control systems to control the speed and direction of their four wheels continuously. Several control methods have been used in recent years to achieve the best control solutions.

The core point of the designed control method is the assurance of the rapid convergence of the system reactions to zero with a finite settle downtime. When a bad controller is used, the required range of the controlled speed for FWDS may be more than the velocity or acceleration upper bound limitations that the motors can produce. Then the control's instruction is not reliable, which leads to poor act and the system will be unstable(Runhua Wang et al., 2021).

One of the control methods used in a four-wheel drive system is a smooth control method, but the convergence performance is not perfect, and the smooth control method is not an optimal time controller (Ariff et al., 2015; Shuai et al., 2014; Rongrong Wang et al., 2015). On the other hand, a slide mode control has anti-disturbance performance and fast convergence. But it is asymptotically stable and not continuous. This may lead to being chatter in a closed-loop feedback system (Ginoya et al., 2014; Li et al., 2017). Due to the simplicity of the Proportional Integral Derivative (PID) structure, it is one of the most used control methods for FWDSs. But PID controller has limitations when they are tuned to deal with specific conditions and if these conditions are changed, the performance will be affected. Also, the PID controllers do not work for nonlinear systems (Jeong et al., 2017; J. Wang, 2020; Zhou et al., 2018). Artificial Neural networks (ANN) are the forming of the human mind which are used widely in control fields. The major difficulty of ANN is working as a black box. It does not explain the way that the solution was done, and hence, decreases the belief in the network. (Chen et al., 2020; Kortylewski et al., 2021; Kraft et al., 2019; Tu, 1996). In contrast, the finite-time controller in comparison to the mentioned controllers promises better performance.

The FTC is popular due to its excessive tracking precision, fast convergence, and powerful disturbance refusal. Due to advantages of Finite-time controllers over other controllers in which they have excessive tracking precision, fast convergence, and powerful disturbance refusal, lead them to a widely being used in different control areas. In latest years, FTCs have gained more consideration from many researchers in the control area, who have expressed applications in several procedures and systems (Fang et al., 2019; Meng et al., 2018; F. Wang et al., 2019)

This research aims to review previous works in the concept of finite-time approaches in the area of the controller performance of FWDSs. This paper includes the following sections: The introduction is presented in section one. Section two covers the four-wheel drive system mathematical model. Finite-time controller details in section three and section four covers finite-time controllers in different areas of applications. Finally, the conclusion is given in section five.

2. Four-Wheel Drive System Mathematical Model

FWDS has insignificant benefits in terms of dynamic performance, energy effectiveness, and active safety. Additionally, the torque of the FWDS EV can be individually controlled and easily determined. Because the EV's velocity is an essential variable in dynamics control and stability, the estimation of EV's velocity is done in general. Thus, there is no doubt that estimating the accuracy of the EV's velocity is necessary for reaching the high performance of the EV controller(Xin et al., 2017) (Meng et al., 2019).

In FWDS, when a car steers, all four wheels turn at the same time. The lateral motion and the yaw of the FWDS can be controlled by both front and rear wheels, which also decreases the steering force delay and controls the motion trajectory (Meng et al., 2019). Figure 1 demonstrates the FWDS dynamic model.

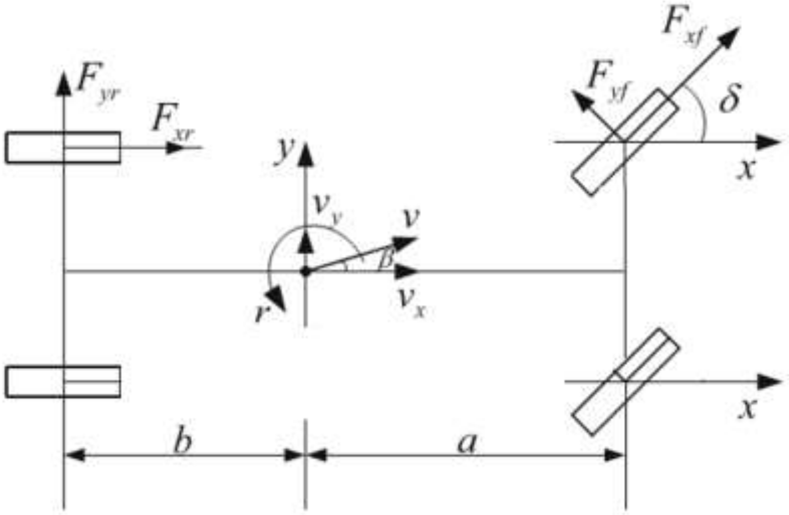

Figure 1. FWDS Dynamic Model (Ding & Sun, 2017).

Where δ is the steering angle ($\delta \geq 0$ for anticlockwise and $\delta < 0$ for clockwise), β is the EV sideslip angle; a and b are the distances between the center of gravity and the front axle and rear axle. V is the velocity of EV; v_x represents the longitudinal velocity of EV; v_y indicates the lateral velocity of EV. Fxf, Fyf, Fxr and Fyr are the front and rear wheels tire forces.

The controlling of the speed and direction by both the front and rear wheels and controlling the motion trajectory can be done with the use of FWDS.

The lateral motion can be described as:

$$m(\dot{v}_y + r.v_x) = -\frac{2}{v_x}(aK_f-bK_r)r + 2K_f\delta-2(K_f-K_r)\beta \qquad (1)$$

and the motion of yaw stated as:

$$I_z\dot{r} = 2aK_f\delta-\frac{2}{v_x}(a^2K_f-b^2K_r)r + 2(aK_f-bK_r)\beta \qquad (2)$$

where K_f and K_r denotes the front and rear wheels cornering stiffnesses respectively (Ding & Sun, 2017).

3. Finite-Time Controller

The idea of finite-time control dates back to the Fiftieth of last century when the idea of finite-time stability (FTS) was introduced by Kamenkov (Kamenkov, 1953). In 1965, Weiss and Infante (Weiss & Infante, 1965) published a very comprehensive analysis of FTS for nonlinear systems, with the perception of finite-time stability. Soon thereafter, Weiss and Infante published an addition of FTS to nonlinear systems in the presence of perturbation signals and developed the idea of Bounded Input and Bounded Output (BIBO) finite-time stability (WEISS & INFANTE, 1967). Nowadays, generally BIBO known as finite time-bounded (FTB) stability (F. Amato et al., 2015). (Wu, 1969) protracted several of the present analysis outcomes on Finite-Time Stability for continuous-time to discrete-time systems.

In 1997, Dorato, Abdallah, and Famularo (Dorato et al., 1997) presented a study on the strong Finite-Time Stability proposal for linear systems. They used linear matrix variations to find state-feedback control rules. Additional linear matrix variations based on design outcomes for linear systems were existing in Amato *et al.* (F. C. D. Amato, 2003). In 2002, Abdallah *et al.* proposed methods which are depending on statistic learning for Finite-Time Stability design with static output feedback. Lately, discrete-time FTS design methods was used in the control of ATM nets and systems with net-control (Mastellone et al., 2006).

(Sun et al., 2017) suggested a new control strategy to unify the structure of Lyapunov utilities for a finite-time stability statement. The design of an FTC was done for steering of four-wheel of an EV to improve the stability of the EV (Meng et al., 2018). A finite-time controller was designed to stabilize the electric vehicle in case a tire had blown out (Meng et al., 2019). (Lin et al., 2019) examined the bounded finite-time of a neutral type switched systems with delay in time-vary.

A system is thought to be finite-time stable when bounded with the initial condition, its state does not overdo a definite threshold during an identified period (Osiris et al., 2018). The finite-time control problem concerns the design of a linear controller which guarantees the FTS of the closed-loop system. (Francesco Amato et al., 2006)

The next explanations deal with several FTC difficulties.

The definition of FTS: Given positive scalars c_1, c_2, T, with $c_1 < c_2$, and a positive definite symmetric matrix function $\Gamma(t)$ is between $[0, T]$, the time-varying linear system:

$$\dot{x}(t) = A(t)x(t), \qquad x(0) = x_0 \tag{3}$$

is supposed to be finite-time stable (FTS) with respect to $(c_1, c_2, T, \Gamma(t))$, if

$$x_0^T\Gamma(0)x_0 \le c_1 \Rightarrow x(t)^T\Gamma(t)x(t) < c_2 \ \forall t \in [0, T] \tag{4}$$

3.1. FTC via State Feedback:

For the time changes the linear system

$$\dot{x}(t) = A(t)x(t) + B(t)u(t) + G(t)w(t), x(0) = x_0 \tag{5}$$

where $w(t)$ is the disturbance, $u(t)$ is the control input. A state feedback controller in the form

$$u(t) = K(t)x(t) \tag{6}$$

The closed-loop system is found by connecting (3) and (4)

$$\dot{x}(t) = \big(A(t) + B(t)K(t)\big)x(t) + G(t)w(t), \ x(0) = x_0 \tag{7}$$

3.2. FTC via Output Feedback:

Assume the system with linear time-varying

$$\dot{x}(t) = A(t)x(t) + B(t)u(t) + G(t)w(t), x(0) = x_0 \tag{8}$$

$$y(t) = C(t)x(t) + H(t)w(t) \tag{9}$$

A dynamic output feedback controller in the form

$$\dot{x}_c(t) = A_K(t)x_c(t) + B_K(t)y(t) \tag{10}$$

$$u(t) = C_K(t)x_c(t) + D_K(t)y(t) \tag{11}$$

where $x_c(t)$ has the similar dimension of $x(t)$, such that the closed-loop system is initiated by connecting (8), (9), (10), and (11).

4. Finite-Time Control: Approaches and Review

This section discusses serval papers that show the use of finite-time controllers in different areas of applications.

Starting from the spacecraft area; A finite time neural scheme control is used by (Tao et al., 2021) for spacecraft with attitude tracking presentation using finite-time performance function to guarantee parametric uncertainty, external disturbance, unmeasurable flexible vibration, and the saturation of actuator. The finite-time controller guarantees that errors of tracking can be converged to a given range within a determined time, which is not dependent on the initial conditions. The resultant control is then protracted by a neural network compensator to remove the disturbance and overcome the unlimited actuator saturation. Finally, the results and the numerical simulations prove the stability, effectiveness, and robustness of the used controller.

For motor control; the authors of (Du et al., 2021) designed a finite-time controller to resolve the speed regulation control problem of a permanent magnet synchronous motor under the control input constraints. The work of this paper was in two aspects. First, abounded finite-time feedback control method is designed to develop the scheme and sidestep the saturation limitation problem. The second part is to develop the scheme's disturbance rejection capability. The proposed finite-time control-based speed regulation controller scheme is shown in Figure 2. The authors claimed that their results show the effectiveness in disturbance rejection.

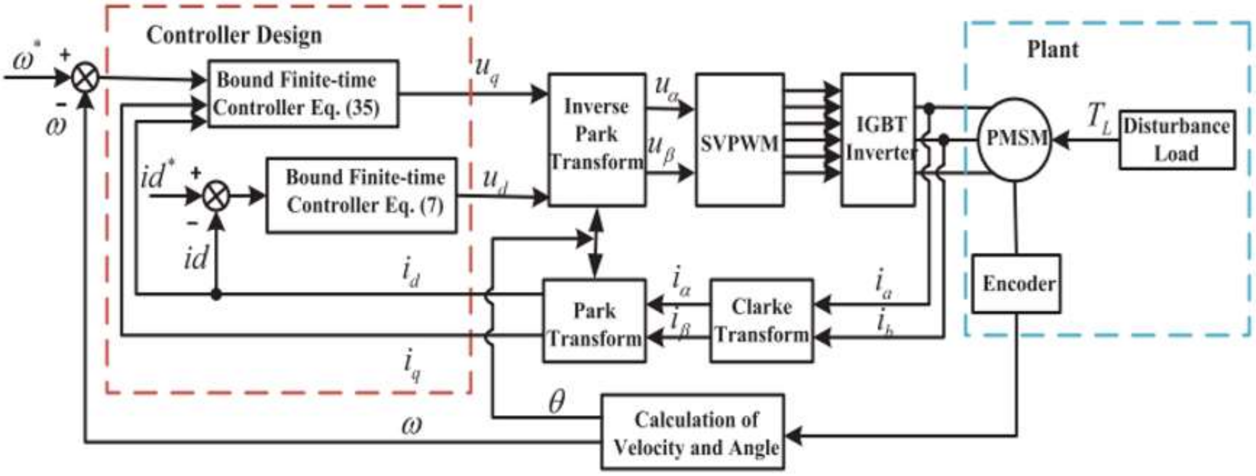

Figure 2. Finite-Time Control Based Speed Regulation Controller (Du et al., 2021).

An adaptive recursive terminal sliding mode (ARTSM) controller was recommended in (Shao et al., 2020). The recommended controller assured that the tracking error converges to zero in a finite time. Additionally, by choosing a suitable initial value for the integral controller component, the proposed controller was forced to begin on the sliding surface at the starting time such that the completion time is decreased. Analysis of stability was also showed the verification of the convergence of finite-time and without error of tracking of the closed-loop scheme in the suggested control system. Experiment outcomes demonstrated the efficiency of the proposed control system in terms of reduction of tracking errors and fast disturbance refusal as authors claimed in their work.

The main aim of the work (González-García et al., 2021) was to reduce the power that was consumed by the controller of the Unmanned Underwater Vehicles BlueROV2 model. The reduction was done by implementing a model-free high-order sliding-mode finite-time controller as shown in Figure 3. Results showed that the finite-time convergence to zero faster than other controllers such as PID, Feedback Linearization, and Lyapunov-Based. So, the proposed finite-time controller was up to 50% in the power consumption reduction when compared to other mentioned controllers.

The authors of (Mei et al., 2020) have improved an FTC for various integrator nonlinear systems that are subjected to saturated input control of an agricultural vehicle straightforward line tracking scheme. A saturated FTC with an adaptable saturation level was considered by imposing a series of saturation tasks on the unsaturated control system as shown in Figure 4. The mathematical evidence indicated that with the presence of the control system, the states of the system will be determined to a specified region which was driven by the level of saturation. The outcomes from simulations of the paper showed that the saturated output could be adjusted by using this finite-time controller when it is unsaturated.

In (Liang et al., 2021) an FTC was suggested for turbo-generators in the existence of limited disturbances and unidentified scheme dynamics. The constant boundaries on the system states and multi-terminal sliding mode were suggested to improve the transient performance. Then, the uncertainties of the scheme were solved by the neural network. Similarly, the essential free of chatter property can be reached by the margin layer. In conclusion, the output of the finite-time stability in the system was verified by using Lyapunov analysis, and simulation outcomes had exposed that the suggested control system could improve both stable accuracy and transient stability in the existence of unidentified external disturbances.

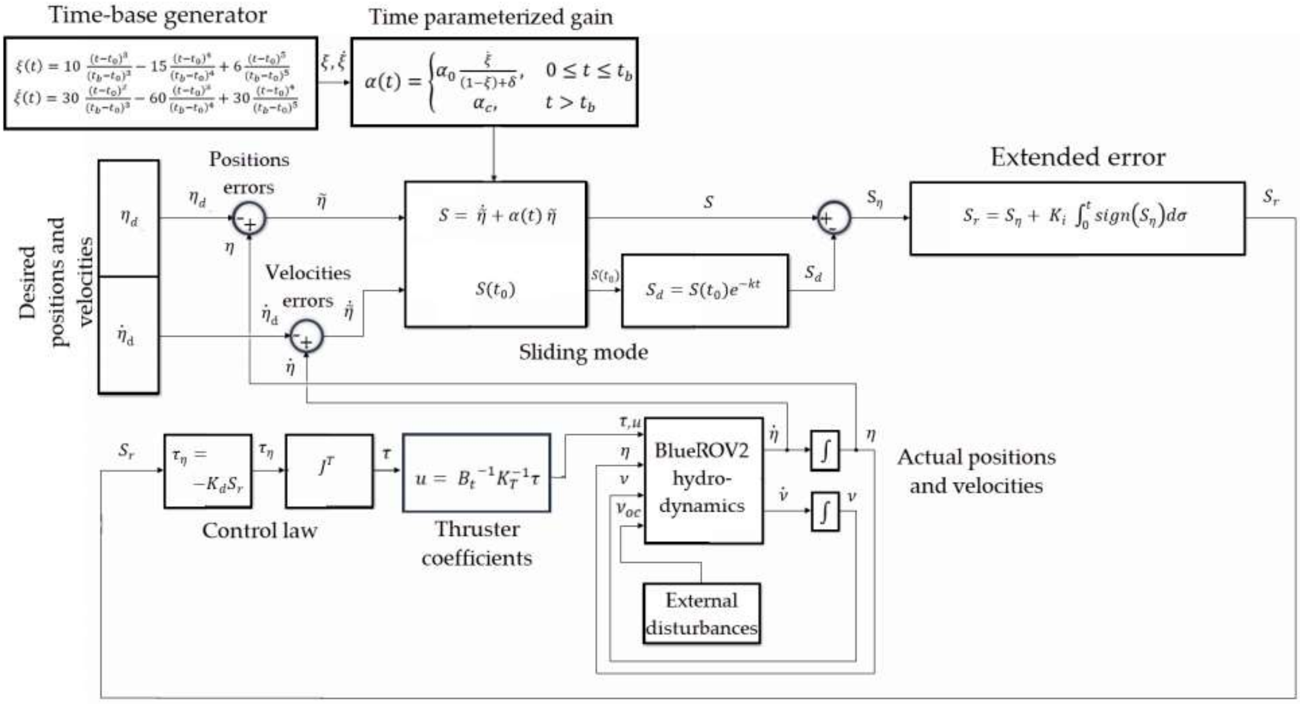

Figure 3. Model-Free High-Order Sliding-Mode Finite-Time Controller (González-García et al., 2021).

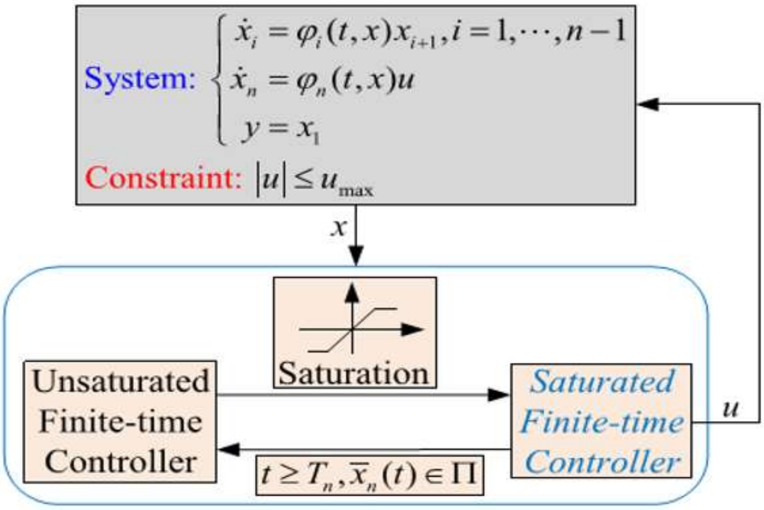

Figure 4. Block Plan Of Control System (Mei et al., 2020).

The article (Nguyen et al., 2019) demonstrated a fuzzy problem of crane structure and boundedness FTS via the sliding mode control technique. Because of the robust coupling of control input, the fuzzy method was applied to linearize the crane structure. Swinging of crane plates and hook which were due to the outer disturbances of the friction and air resistance were solved by using boundedness FTS sliding mode control technique. The simulation results showed the effectiveness of the sliding mode controller technique with finite-time procedure over other present procedures such as similar proportional integral differential (PID) controller, developed neural network procedure, and linear quadratic regulator (LQR).

The authors in (Runhua Wang et al., 2021) proposed an adapted visual tracking control for a mobile robot using a single attached camera and by choosing proper control parameters for both speed and accelerate saturation limitations could be certain. The authors proposed a first-order filter speed control system to guarantee the speed halts at the upper boundary. By using the FTC theory, the acceleration-level control system was improved to track the speed input in a certain time. The control block diagram is shown in Figure 5. In this work, the authors used a Pioneer-3DX type mobile robot, a DMK23G618 model camera for testing the proposed controller. Experimental outcomes showed the efficiency of the suggested control system in saturation limitations.

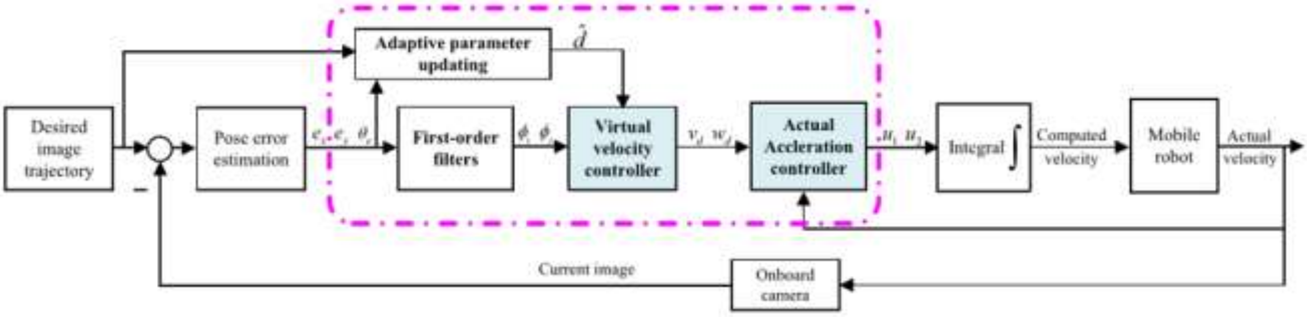

Figure 5. Tracking Control Diagram (Runhua Wang et al., 2021).

A control scheme combining impedance and finite time was proposed by (Hu et al., 2020) in which they used position tracking for robot movement in uncertain environments. The control structure was separated into two integral loops: an outer loop was for controlling the impedance force in order to remove the error of force tracking, while an inner loop was for controlling the position tracking. A control strategy for controlling the robot environment is shown in Figure 6. The Matlab/Simulink simulation results showed that the proposed control can achieve a good tracking effect in all uncertain environments.

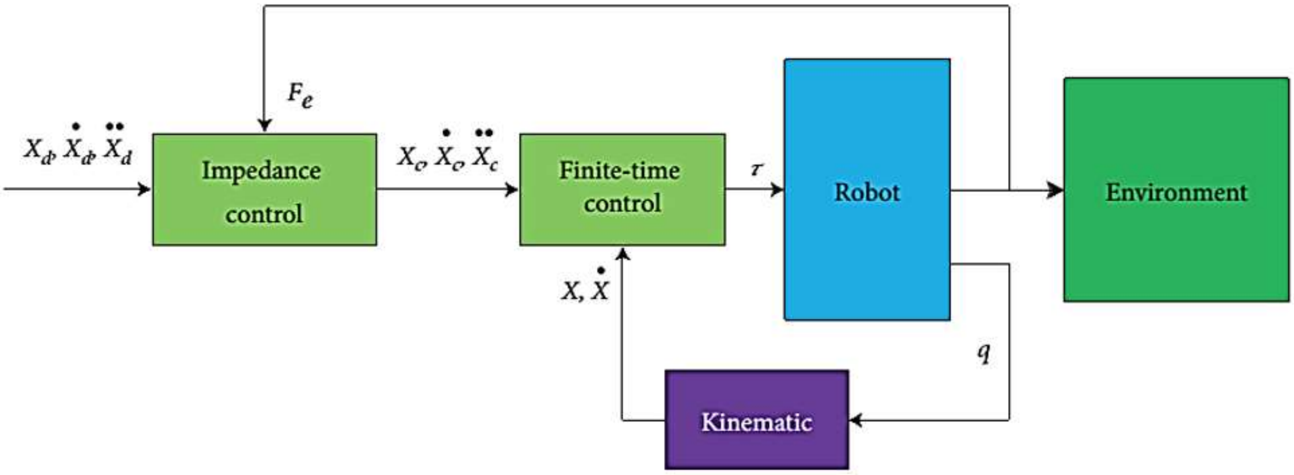

Figure 6. Control Block Diagram (Hu et al., 2020).

The article (Zheng et al., 2019) proposed an analysis of the stability and an improved robust FTC for a mobile robot system with problems of undefined angular and linear speeds and time-changing limited disturbance. The article (Zheng et al., 2019) proposed an analysis of stability and an improved robust FTC for a mobile robot system which had problems of the unmeasurable angular and linear velocities, and time-varying bounded disturbance. They also proposed a solution for solving these problems by using state feedback control laws with a reduction in a sharp change of initial values in state variables. The closed-loop scheme was asymptotically stable and the state errors were converged to modifiable limits by using the Lyapunov–Krasovskii approach. The simulation was done to illustrate the efficacy of the suggested approach.

In four-wheel drive systems, several researchers have discussed them. The authors in (Meng et al., 2018) designed a finite-time convergence controller to control an EV run by four-wheel motors to eliminate uncertainties and keep the sideslip angle to be zero value. The simulation was done by the Carsim software and MATLAB/Simulink to prove that the considered Four-Wheal System (FWS) finite-time convergence control system could track the chosen model, reduce some uncertainties, and retain the sideslip angle to be zero value. The simulation results and from the comparison to the slide mode controller technique showed that the proposed technique has a good control result for the active FWS of an electrical vehicle. The article (Meng et al., 2021) recommended a lane-tracking controller using a non-smooth finite-time control technique. A lane-tracking control prototype was built and a tracking scheme and error weight superposition technique to track error computing for the lane-tracking control were suggested by depending on the given information of the used lane line. The construction of the lane-tracking control is demonstrated in Figure 7. A non-smooth FTC was built for the lane-tracking with the use of the direct Lyapunov technique. The simulations outcomes exposed that the suggested controller is better than the PID controller to keep the vehicle moving in the wanted lane with the different kinds of roads (straight, constant curvature, varied curvature, and S-bend). The work (Meng et al., 2019) studied the problem of a tire blowout controller via output feedback for an EV that is driven by four-wheel motors. To report the problems in approximating the unmeasurable state, unidentified factors, and disturbances for the electric vehicle, a finite-time observer was presented. The tire blowout simulation was done for vehicle speeds: 60 km/h, 80 km/h, and 120 km/h, respectively, to show the validity of the designed controller. The simulations results showed that the validation of the proposed finite-time output feedback controller for the Electric Vehicle Driven by Four Wheels Independently (EV-DFWI) tire blowout control.

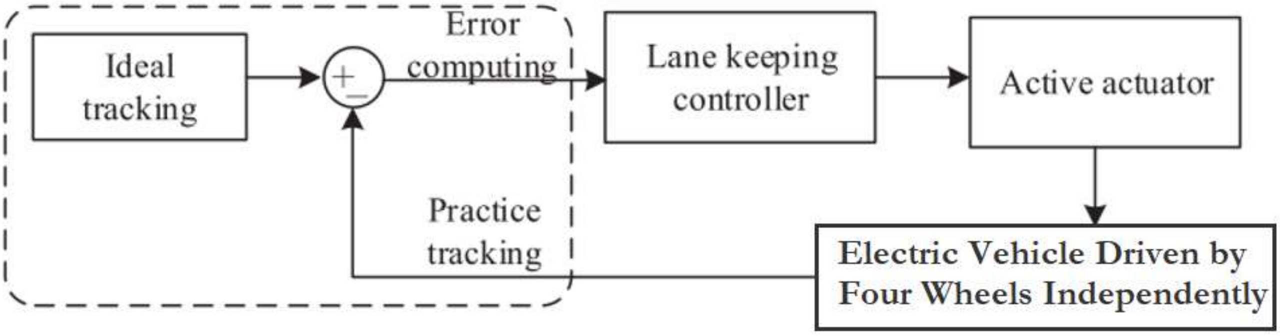

Figure 7. Construction of the Lane-Tracking Control (Meng et al., 2021).

5. Conclusion

To control the speed and direction of the four-wheel drive system serval controller schemes are available to implement. The smooth control method is one of the good methods but its convergence act is not faultless and not an optimal time controller. While the slide mode control has anti-disturbance performance and fast convergence. But the slide mode is asymptotically stable and not continuous that could cause the chattering in the closed-loop feedback system. The PID control is one of the most applied controlling strategies for FWDSs due to their simple structure. But the PID controller does not work for nonlinear systems. ANN is also used widely in control fields but it works as a black box. It does not give an explanation of the way how the solution has been done. The controller techniques for controlling the speed and direction of the four-wheel drive system should be fast convergence of the control, continuous control performance, and solve the external disturbances. These can be done by using the Finite-time controller approach.

References

Amato, F., Ariola, M., Abdallah, C.T., Dorato, P. (August-September 1999). *Dynamic output feedback finite-time control of LTI systems subject to parametric uncertainties and disturbances*. 1999 European Control Conference (ECC). IEEE. Karlsruhe, Germany. doi: 10.23919/ecc.1999.7099716.

Amato, F., Ariola, M., Abdallah, C. T., & Dorato, P. (2015). Dynamic output feedback finite-time control of LTI systems subject to parametric uncertainties and disturbances. *European Control Conference, ECC 1999 - Conference Proceedings*, *37*, 2596–2601. https://doi.org/10.23919/ecc.1999.7099716

Amato, F. C. D. (2003). Necessary and Sufficient Conditions for. *Integration The Vlsi Journal*, *174*, 544–548.

Amato, Francesco, Ariola, M., Carbone, M., & Cosentino, C. (2006). Finite-time control of linear systems: A survey. *Systems and Control: Foundations and Applications*, *9780817643836*, 195–213. https://doi.org/10.1007/0-8176-4470-9_11

Ariff, M. H. M., Zamzuri, H., Nordin, M. A. M., Yahya, W. J., Mazlan, S. A., & Rahman, M. A. A. (2015). Optimal control strategy for low speed and high speed four-wheel-active steering vehicle. *Journal of Mechanical Engineering and Sciences*, *8*(June), 1516–1528. https://doi.org/10.15282/jmes.8.2015.26.0148

Chen, J., Su, J., & Li, J. (2020). Self-Coupling Black Box Model of a Dynamic System Based on ANN and Its Application. *Mathematical Problems in Engineering*, *2020*. https://doi.org/10.1155/2020/5724831

Ding, S., & Sun, J. (2017). Direct yaw-moment control for 4WID electric vehicle via finite-time control technique. *Nonlinear Dynamics*, *88*(1), 239–254. https://doi.org/10.1007/s11071-016-3240-0

Dorato, P., Abdallah, C. T., & Famularo, D. (1997). Robust finite-time stability design via linear matrix inequalities. *Proceedings of the IEEE Conference on Decision and Control*, *2*(December), 1305–1306. https://doi.org/10.1109/cdc.1997.657637

Du, H., Wen, G., Cheng, Y., & Lu, J. (2021). Design and Implementation of Bounded Finite-Time Control Algorithm for Speed Regulation of Permanent Magnet Synchronous Motor. *IEEE Transactions on Industrial Electronics*, *68*(3), 2417–2426. https://doi.org/10.1109/TIE.2020.2973904

Fang, L., Ma, L., Ding, S., & Zhao, D. (2019). Finite-time stabilization for a class of high-order stochastic nonlinear systems with an output constraint. *Applied Mathematics and Computation*, *358*, 63–79. https://doi.org/10.1016/j.amc.2019.03.067

Ginoya, D., Shendge, P. D., & Phadke, S. B. (2014). Sliding mode control for mismatched uncertain systems using an extended disturbance observer. *IEEE Transactions on Industrial Electronics*, *61*(4), 1983–1992. https://doi.org/10.1109/TIE.2013.2271597

González-García, J., Narcizo-Nuci, N. A., García-Valdovinos, L. G., Salgado-Jiménez, T., Gómez-Espinosa, A., Cuan-Urquizo, E., & Cabello, J. A. E. (2021). Model-free high order sliding mode control with finite-time tracking for unmanned underwater vehicles. *Applied Sciences (Switzerland)*, *11*(4), 1–22. https://doi.org/10.3390/app11041836

Hu, H., Wang, X., & Chen, L. (2020). Impedance with Finite-Time Control Scheme for Robot-Environment Interaction. *Mathematical Problems in Engineering*, *2020*. https://doi.org/10.1155/2020/2796590

Jeong, J. H., Lee, D. H., Kim, M., Park, W. H., Byun, G. S., & Oh, S. W. (2017). The study of the electromagnetic robot with a four-wheel drive and applied I-PID system. *Journal of Electrical Engineering and Technology*, *12*(4), 1634–1640. https://doi.org/10.5370/JEET.2017.12.4.1634

Kamenkov, G. (1953). Stability of motion over a finite interval of time. *Journal of Applied Math. and Mechanics*, *17*(2), 529–540.

Kortylewski, A., Liu, Q., Wang, A., Sun, Y., & Yuille, A. (2021). Compositional Convolutional Neural Networks: A Robust and Interpretable Model for Object Recognition Under Occlusion. *International Journal of Computer Vision*, *129*(3), 736–760. https://doi.org/10.1007/s11263-020-01401-3

Kraft, S., Causse, J., & Martinez, A. (2019). Black-box modelling of nonlinear railway vehicle dynamics for track geometry assessment using neural networks. *Vehicle System Dynamics*, *57*(9), 1241–1270. https://doi.org/10.1080/00423114.2018.1497186

Li, H., Shi, P., & Yao, D. (2017). Adaptive Sliding-Mode Control of Markov Jump Nonlinear Systems with Actuator Faults. *IEEE Transactions on Automatic Control*, *62*(4), 1933–1939. https://doi.org/10.1109/TAC.2016.2588885

Liang, Q., Yang, Q., Meng, W., & Li, Y. (2021). Adaptive finite-time control for turbo-generator of power systems with prescribed performance. *Asian Journal of Control*, *February*, 1–12. https://doi.org/10.1002/asjc.2553

Lin, X., Yang, Z., & Li, S. (2019). Finite-time boundedness and finite-time weighted L2-gain analysis for a class of neutral type switched systems with time-varying delays. *International Journal of Systems Science*, *50*(9), 1703–1717. https://doi.org/10.1080/00207721.2019.1622816

Mastellone, S., Dorato, P., & Abdallah, C. T. (2006). Finite-time stability for nonlinear networked control systems. *Systems and Control: Foundations and Applications*, *9780817643836*, 535–553. https://doi.org/10.1007/0-8176-4470-9_29

Mei, K., Ma, L., He, R., & Ding, S. (2020). Finite-time controller design of multiple integrator nonlinear systems with input saturation. *Applied Mathematics and Computation*, *372*. https://doi.org/10.1016/j.amc.2019.124986

Meng, Q., Qian, C., & Sun, Z. Y. (2019). Finite-time stability control of an electric vehicle under tyre blowout. *Transactions of the Institute of Measurement and Control*, *41*(5), 1395–1404. https://doi.org/10.1177/0142331218780967

Meng, Q., Sun, Z. Y., & Li, Y. (2018). Finite-time Controller Design for Four-wheel-steering of Electric Vehicle Driven by Four In-wheel Motors. *International Journal of Control, Automation and Systems*, *16*(4), 1814–1823. https://doi.org/10.1007/s12555-017-0509-0

Meng, Q., Zhao, X., Hu, C., & Sun, Z. Y. (2021). High velocity lane keeping control method based on the non-smooth finite-time control for electric vehicle driven by four wheels independently. *Electronics (Switzerland)*, *10*(6). https://doi.org/10.3390/electronics10060760

Nguyen, V. T., Yang, C., Du, C., & Liao, L. (2019). Design and implementation of finite time sliding mode controller for fuzzy overhead crane system. *ISA Transactions*. https://doi.org/10.1016/j.isatra.2019.11.037

Osiris, O., Villegas, V., Nandayapa, M., & Soto, I. (2018). Advanced topics on computer vision, control and robotics in mechatronics. In *Advanced Topics on Computer Vision, Control and Robotics in Mechatronics*. Springer Verlag. https://doi.org/10.1007/978-3-319-77770-2

Shao, K., Zheng, J., Huang, K., Wang, H., Man, Z., & Fu, M. (2020). Finite-Time Control of a Linear Motor Positioner Using Adaptive Recursive Terminal Sliding Mode. *IEEE Transactions on Industrial Electronics*, *67*(8), 6659–6668. https://doi.org/10.1109/TIE.2019.2937062

Shuai, Z., Zhang, H., Wang, J., Li, J., & Ouyang, M. (2014). Lateral motion control for four-wheel-independent-drive electric vehicles using optimal torque allocation and dynamic message priority scheduling. *Control Engineering Practice*, *24*(1), 55–66. https://doi.org/10.1016/j.conengprac.2013.11.012

Sun, Z. Y., Yun, M. M., & Li, T. (2017). A new approach to fast global finite-time stabilization of high-order nonlinear system. *Automatica*, *81*, 455–463. https://doi.org/10.1016/j.automatica.2017.04.024

Tao, J., Zhang, T., & Liu, Q. (2021). Novel finite-time adaptive neural control of flexible spacecraft with actuator constraints and prescribed attitude tracking performance. *Acta Astronautica*, *179*, 646–658. https://doi.org/10.1016/j.actaastro.2020.10.010

Tu, J. V. (1996). Advantages and disadvantages of using artificial neural networks versus logistic regression for predicting medical outcomes. *Journal of Clinical Epidemiology*, *49*(11), 1225–1231. https://doi.org/10.1016/S0895-4356(96)00002-9

Wang, F., Liu, Z., Zhang, Y., & Chen, C. L. P. (2019). Adaptive finite-time control of stochastic nonlinear systems with actuator failures. *Fuzzy Sets and Systems*, *374*, 170–183. https://doi.org/10.1016/j.fss.2018.12.005

Wang, J. (2020). Application of pid algorithm in drive fault-tolerant control of four-wheel drive electric vehicle. *International Journal of Mechatronics and Applied Mechanics*, *1*(8). https://doi.org/10.17683/ijomam/issue8.29

Wang, Rongrong, Hu, C., Wang, Z., Yan, F., & Chen, N. (2015). Integrated optimal dynamics control of 4WD4WS electric ground vehicle with tire-road frictional coefficient estimation. *Mechanical Systems and Signal Processing*, *60*, 727–741. https://doi.org/10.1016/j.ymssp.2014.12.026

Wang, Runhua, Zhang, X., & Fang, Y. (2021). Visual tracking of mobile robots with both velocity and acceleration saturation constraints. *Mechanical Systems and Signal Processing*, *150*, 107274. https://doi.org/10.1016/j.ymssp.2020.107274

Weiss, L., & Infante, E. F. (1965). on the Stability of Systems Defined Over a Finite Time Interval. *Proceedings of the National Academy of Sciences*, *54*(1), 44–48. https://doi.org/10.1073/pnas.54.1.44

WEISS, L., & INFANTE, E. F. (1967). Finite Time Stability Under Perturbing Forces and on Product Spaces. *IEEE Transactions on Automatic Control*, *AC-12*(1), 54–59. https://doi.org/10.1109/TAC.1967.1098483

Wu, S. H. (1969). Stability of discrete systems over a finite interval of time. *International Journal of Control*, *9*(6), 679–693. https://doi.org/10.1080/00207176908905789

Xin, X., Zhang, W., Shen, C., & Zheng, H. (2017). Control strategy of four-wheel independent drive electric vehicle based on vehicle velocity estimation and switchover. *Transactions of the Institute of Measurement and Control*, *39*(7), 965–975. https://doi.org/10.1177/0142331215625767

Zheng, W., Wang, H., Sun, F., Li, X., & Wen, S. (2019). Finite-time control of mobile robot systems with unmeasurable angular and linear velocities via bioinspired neurodynamics approach. *Applied Soft Computing Journal*, *85*. https://doi.org/10.1016/j.asoc.2019.105753

Zhou, H., Jia, F., Jing, H., Liu, Z., & Güvenç, L. (2018). Coordinated Longitudinal and Lateral Motion Control for Four Wheel Independent Motor-Drive Electric Vehicle. *IEEE Transactions on Vehicular Technology*, *67*(5), 3782–3790. https://doi.org/10.1109/TVT.2018.2816936