Chapter 17
Soft-Computing-Based Real-Time Control of Two Wheel Mobile Robot (TWMR)

Ashwani Kharola
Tulas Institute, India

Suyashi Raiwani
EXL Services, India

Shristi Kharola
Graphic Era University, India

ABSTRACT

This chapter considers various soft-computing techniques for control of self-balancing two wheel mobile robot (TWMR). Initially, a mathematical model of the system was developed using Newton's second law. Thereafter, a simulink of the proposed system was developed in Matlab Simulink environment. Two different controllers, namely fuzzy logic controller and ANFIS controller, were used for control of proposed system. Finally, a real-time model of TWMR was designed which was controlled using Arduino Uno microcontroller, and its results were used for training of ANFIS controller.

1.0 INTRODUCTION

Robotic systems comprises of elements of complex configurations which are keen source of interest for researchers in the past few decades (Yasuda, 2016). Two-wheel mobile robot (TWMR) is a complex dynamical configuration of robot in which a single rotating wheel is replaced by two identical rotating wheels (Pham *et al.,* 2017). The configuration of the system increases its nonlinearity thereby making it difficult to control (Melkou & Hamerlain, 2014). The objective remains same to stabilise chassis and wheels at upright angle and at particular position in presence of external uncertainities and disturbances (Ghabi *et al*., 2018). Watanabe (1993) recommended a fuzzy gaussian neural control for position and

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azimuth angle regulation of a two-wheel movable machine. The author designed the proposed controller using gaussian shape neural networks having different configuration and weighted connections. A simplified model of two-input and two-output fuzzy neural controller having 49 fuzzy rules was considered in the study. The study can be further extended to a balance control problem. In a study by Ruan *et al.* (2008) reinforcement learning based fuzzy neural controller was successfully applied for motion control of a double-wheel portable robotic vehicle. The outcomes illustrated that above technique was capable of controlling robot in different positions quickly compared to conventional PID control. There is a scope for further improvement of settling time below 5.0 sec by increasing the number of hidden neurons. A real-time stabilisation of double-wheel mutable robotic assembly was proposed by Abeygunawardhana and Murakami (2008). The authors designed a self-tuned PD controller which was capable of adjusting their gains automatically for control of proposed system.

An adaptive fuzzy based approach for regulating motion of two-wheeled standing robot was proposed by Ruan *et al*. (2009). The controller was capable of stabilising the system in large initial angles and provides better stability. As an extension to future work real-time control of proposed system can be achieved for better validation. Goher *et al*. (2010) presented a strategy for stabilisation of a double-wheel robotic manipulator carrying different loads. The study considered a PD and PD-fuzzy controller for control of the proposed system. Results highlighted improved performance of fuzzy-PD approach in contrast to PD controller. The fuzzy controller was designed using five triangular shape memberships and the settling time obtained to control robot position was around 100 sec. The performance can be surely improved by either changing the fuzzy control rules or changing the shape and number of memberships. In a study by Wu and Zhang (2011), pole placement feedback technique was compared to fuzzy control in order to stabilse a double-wheel self-balancing robotic manipulator. A structural model of proposed system was built using kinetic equations derived using Newton dynamics. Simulations confirmed that fuzzy control resulted in lesser stabilisation time whereas pole placement control resulted in lower overshoot compared to fuzzy control.

Ahmad *et al*. (2011) constructed a modular fuzzy controller for regulating an extremely unstable two-wheel wheelchair configuration. A two-link model of typical wheelchair system was developed in Visual Nastran software and its control was confirmed in Matlab. Vermeiren *et al.* (2011) presented a study which considered modeling and control of a two-wheeled Segway called B2. The authors derived a parallel distribution compensation algorithm based on takagi-sugeno fuzzy model to stabilise above system in real-time. The steady state error of the system can to be improved to yield better stabilisation. A two-wheel robotic vehicle carrying a payload was controlled using a PID and fuzzy controller by Almeshal *et al.* (2013). The fuzzy controller was designed using five bell shape membership functions. The results showed that fuzzy controller minimised the overshoot and settle time with lesser disturbances compared to other controller. A real-time model of proposed system can be further constructed for better validation and control. A comparison study for balancing of a two-wheel transportable robot was proposed by Wen *et al*. (2013). This study also compared fuzzy and PID controllers for stabilisation of proposed system in terms of balanced efficacy and disturbance rejection ability. Results showed that both the control scheme were able to stabilise the proposed system but fuzzy control again provides better results. Bature *et al*. (2014) performed comparison study of three dissimilar balancing approaches namely fuzzy reasoning, LQR and PID for regulation of a double-wheel inverted pendulum system. The outcomes of the controllers were validated and compared through experiments conducted in real-time. The fallouts illustrated enhanced performance of fuzzy controller when compared to other two control approaches. The PID controller gives the maximum overshoot and settling time response compared to other two controllers.