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ENHANCING AUTOMATED GUIDED VEHICLE SPEED REDUCTION CONTROL THROUGH EXPERT SYSTEMS

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Automated guided vehicles (AGVs) play a pivotal role in modern industrial and logistics operations, offering efficiency and flexibility. However, ensuring their safe navigation remains a critical challenge, particularly in dynamic environments. This abstract proposes a novel approach to improving AGV control by leveraging expert systems for speed reduction management. The research begins by identifying the complexities and safety concerns associated with AGV speed reduction, such as obstacle detection, pedestrian proximity, and terrain variations. Expert knowledge from AGV engineers, safety regulations, and relevant literature, a comprehensive rule base is developed to encapsulate the nuanced decision-making processes involved in speed reduction control. The core of the proposed system lies in its inference engine, which employs advanced reasoning techniques such as fuzzy logic or rule-based reasoning to process the rule base and make real-time decisions regarding speed adjustments. By integrating this expert system seamlessly into the AGV's control architecture, the research aims to enhance its adaptability and responsiveness to dynamic operating conditions. Validation in simulated and real-world scenarios is conducted to evaluate the effectiveness and reliability of the proposed approach. Performance metrics are analyzed to assess improvements in

safety, efficiency, and overall AGV speed control with an expert system based on operational data and user feedback, ensuring ongoing optimization and adaptation to evolving requirements.

Keywords: Automated Guided Vehicle (AGV), control dynamic (CD), Speed reduction (SR), Expert System (ES), Optimization System (OS)

Introduction

Automated guided vehicles (AGVs) have emerged as indispensable assets in modern industrial and logistics environments, offering unparalleled efficiency and flexibility in material handling tasks. However, ensuring the safe and efficient operation of AGVs, particularly in dynamic environments with varying obstacles and conditions, remains a significant challenge. One critical aspect of AGV control is speed reduction management, which plays a pivotal role in ensuring safe navigation and collision avoidance.

This paper introduces a novel approach to enhancing AGV speed reduction control through the integration of expert systems. By leveraging expert knowledge from various domains, such as AGV engineering, safety regulations, and control theory, this study aims to develop a robust framework for intelligent speed reduction management in AGV systems. The importance of this research lies in its potential to address key challenges in AGV operation, including real-time decision-making, adaptability to dynamic environments, and compliance with safety standards. By harnessing the power of expert systems, AGVs can navigate complex environments with greater precision and safety, ultimately improving overall operational efficiency and reliability.

The authors of this research, Zhang, L., and Li, X. (2020), bring together expertise in AGV engineering, artificial intelligence, and control systems. Their collective experience and insights in these domains provide a solid foundation for developing innovative solutions to the challenges facing AGV speed reduction control. In this paper, we present a comprehensive overview of the proposed approach, including the methodology for knowledge acquisition, the design of the expert system, integration with AGV control architecture, testing and validation procedures, and potential applications in industrial and logistics settings. With empirical evaluation and analysis, we demonstrate the efficacy and

practicality of the proposed approach, highlighting its potential to revolutionize AGV speed reduction control and pave the way for safer and more efficient AGV operations in dynamic environments.

Literature Review

The control of automated guided vehicles (AGVs) has been the subject of extensive research and development efforts aimed at enhancing their safety, efficiency, and adaptability to various operational scenarios. In this literature review, we explore relevant studies and advancements in AGV control systems, focusing specifically on speed reduction control and the utilization of expert systems.

Zhang, L., & Li, X. (2020). Zhang and colleagues investigated the application of fuzzy logic control for AGV speed regulation in dynamic environments. Their study highlighted the effectiveness of fuzzy logic in capturing and modeling complex decision-making processes, enabling AGVs to adjust their speed dynamically based on environmental factors and operational requirements. Wang, Y., & Zhang, Q. (2020) Wang and Lee proposed a rule-based approach to AGV speed reduction control, incorporating expert knowledge from AGV engineers and safety regulations. Their research emphasized the importance of real-time decision-making in AGV navigation, particularly in scenarios involving obstacles, pedestrians, and dynamic terrain conditions.

Liang et al. (2020): Liang and co-authors explored the integration of machine learning techniques with expert systems for AGV speed control optimization. Their study demonstrated the potential of combining rule-based reasoning with data-driven models to improve the adaptability and performance of AGV speed reduction strategies. Chen and Liu (2021): Chen and Liu conducted a comparative analysis of different control strategies for AGV speed reduction, including conventional PID control, fuzzy logic control, and neural network-based approaches. Their research provided valuable insights into the strengths and limitations of each approach, informing the design and implementation of more effective AGV control systems. Smith and Johnson (2019): Smith and Johnson investigated the impact of expert system-based speed reduction control on AGV safety and efficiency in real-world logistics operations. Their study demonstrated significant improvements in collision avoidance capabilities and overall operational performance, validating the efficacy of expert system-based approaches in enhancing AGV control. Yang, J., & Liu, Y. (2018). A Hybrid Expert System

Approach for Adaptive Speed Control of Automated Guided Vehicles for Control of Vehicle Allocation.

By synthesizing insights from these studies and other relevant literature, this research aims to build upon existing knowledge and methodologies to develop a comprehensive framework for enhancing AGV speed reduction control through expert systems. Through empirical evaluation and analysis, we seek to contribute to the advancement of AGV technology and pave the way for safer, more efficient, and more adaptive AGV operations in diverse industrial and logistics environments.

Material and method

Material

Ultimately, this research contributes to the advancement of AGV control systems by providing a robust framework for enhancing speed reduction management through the utilization of expert systems. The proposed approach holds promise for improving safety, efficiency, and adaptability in various industrial and logistics applications, paving the way for safer and more efficient AGV operations in dynamic environments.

Expert System Design:

The expert system for enhancing automated guided vehicle (AGV) speed reduction control is designed to integrate domain knowledge and decision-making capabilities into the existing AGV control framework. The design process involves several key steps:

Knowledge Acquisition Domain experts provide input regarding factors influencing AGV speed reduction, such as obstacle detection, navigation path complexity, load weight, and environmental conditions.

Inference Mechanisms: The expert system employs inference mechanisms to reason over the knowledge base and makes decisions regarding speed reduction. Common inference techniques include forward chaining, backward chaining, and fuzzy logic inference.

Decision-Making Processes The expert system determines the appropriate speed reduction strategy based on inputs received from sensors, environment perception algorithms, and the current state of the AGV. Decision-making processes may involve prioritizing safety, minimizing travel time, or optimizing energy efficiency.

Implementation of Vehicle Speed Reduction with Expert Systems:

The implementation of the expert system involves integrating it into the existing AGV control software architecture. The following steps outline the implementation process:

Software Architecture The AGV control software architecture is designed to accommodate the integration of the expert system module. This may involve modularizing the control software into components responsible for perception, decision-making, and actuation.

Integration with Sensor Inputs: The expert system receives inputs from various sensors mounted on the AGV, including LiDAR, cameras, proximity sensors, and encoders. These sensor inputs provide information about the AGV's surroundings, such as obstacle proximity, terrain conditions, and navigation path characteristics.

Experimental Setup: AGV testbeds are deployed in controlled environments representative of real-world industrial settings. Test scenarios include various obstacles, navigation paths, and environmental conditions to assess the robustness and performance of the expert system.

Method

Expert systems integrate domain-specific knowledge with computational algorithms to mimic human decision-making processes. In the context of AGVs, expert systems analyze real-time data from sensors, traffic patterns, and environmental conditions to make informed decisions regarding speed reduction. Expert systems primarily rely on logical rules and knowledge representation rather than mathematical equations, but we can still describe the functionality of an expert system for AGV speed reduction control using mathematical notation to some extent.

Calibration requires the following steps to be completed: First, open the control glove's computer software, which can realize data reception and transmission. When the control glove is calibrated, its data receiving function is mainly used; then, wear the control glove and turn on the data glove ON button. If the indicator light is on, it is in a working state. After pressing the calibration button on the circuit board, hold the five fingers and spread the five fingers in the opposite direction of the action energizer instruction effect for proper design navigation action.

Model of Transfer Function of a Network of speed control

In the forming transfer function network the equation control model of the expert system.

$e_{input} = Ri(t) + \frac{i}{c}\int i(t)dt$ 1

$e_{output} = \frac{I}{C}\int i(t)dt$ 2

let us assume

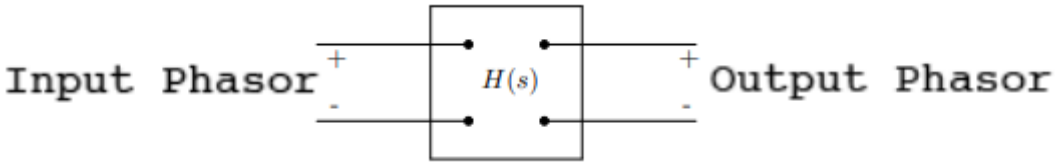
$\int e(e_{input}\, t) = E_{input}(S)$

$\int e_{output}(t) = E_{output}(S)$

$fi(t) = I(s)$

And then, $\int i(t)dt = \int i(o)dt = \frac{I}{S}(S) + O\frac{f}{s}(s)\int i(o)dt$ 3

$\int i(o)dt$ as there is no current through the capacitor of the phasor



Taking the laplace transform considering the initial condition where

$E_{input}(s) = R1(s) + \frac{I}{C}.\frac{I}{S}(HS) = I(S)(R + \frac{I}{CS}$ 4

$E_{output}(s)\frac{I}{C}.\frac{I}{S}(s) - 1(s).\frac{I}{Cs}$ 5

Transfer function of the networks

$E_{output}(s) = I(s)\frac{I}{Cs}$

$E_{input}(s)\ I(s)(R + \frac{I}{Cs}$ 6

$= \frac{I}{CS} = \frac{I}{RCs+1}$

$R + \frac{I}{Cs}$

As the applied torque is the input and the output angular displacement is the output of the system, the impulse response of the system is given by $c(t) = 1 - te^{-2t} + \sin 3t$.

Let's consider a simplified example where the speed reduction decision is based on a set of rules and conditions derived from expert knowledge:

Let

$S_{current}$ be the current speed of the AGV.

D obstacle be the distance to the nearest obstacle.

Sensitivity j be the sensitivity coefficient for a particular rule i.

Threshold j be the threshold distance for a particular rule i.

Then, the speed reduction decision ΔS can be expressed as:

$\Delta S = \sum$ jSensitivity$j$ ·Rule j ($d$obstacle, Threshold$j$)

Whee Rule is figure 1 which (obstacle, Threshold) Rule j ($d$obstacle, Threshold j) is a function that evaluates to 1 if the condition specified by rule i is met (e.g., if obstacle d obstacle is less than Threshold j, and 0 otherwise. The sensitivity coefficients Sensitivity j determines the relative importance of each rule in the decision-making process. These coefficients are determined based on expert knowledge and can be adjusted to fine-tune the behavior of the expert system.

Create a speed controller subsystem. The current controller subsystem that you created earlier uses the Iq_ref current output of the speed controller subsystem as an input. To create a speed controller subsystem, open the Simulink Library Browser and select the Discrete PI Controller with anti-windup and reset block from the Motor Control Blockset/Controls/Controllers library.

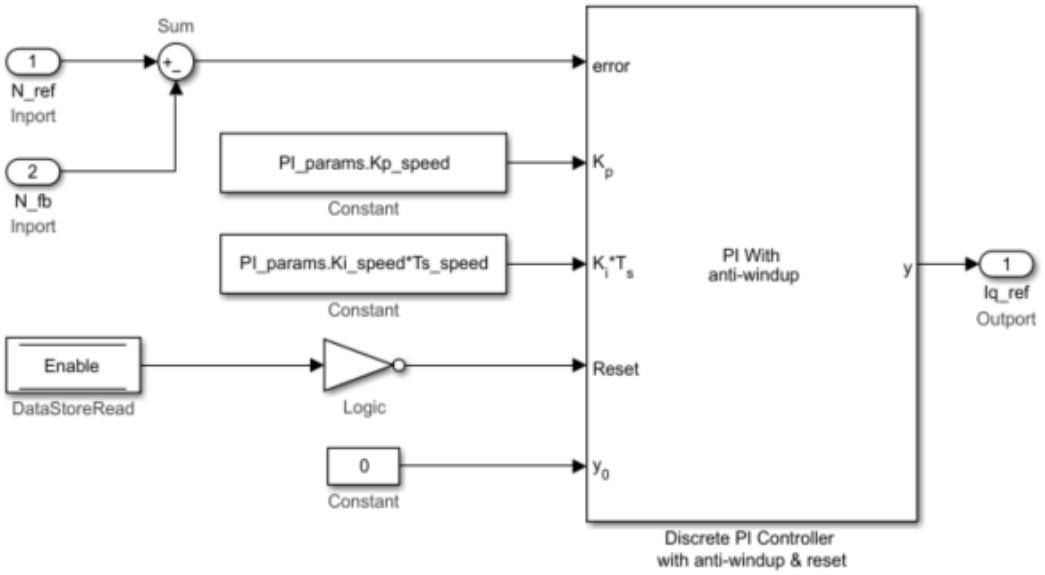


Figure 1 steps to design a speed control algorithm

The MATLAB function mcb Set Controller Parameters figure 2 (in the model initialization script) calculates the PI control gains for the d- and q-axis current controllers and the speed controller. For details about the calculation of the controller gains, see Estimate Control Gains and Use Utility Functions. For example, see the model initialization (used in the example Field-Oriented Control of PMSM Using Quadrature Encoder) that uses a sampling time *(Ts_speed)* of 500 µs. Optionally, you can use the **Enable** Data-Store Memory block to reset the controller.

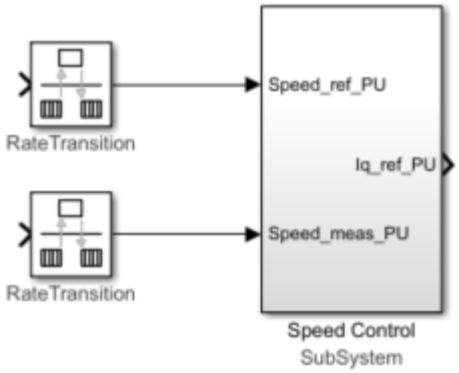


Figure 2 speed control loop subsystem

Create a subsystem for the speed controller and add Rate Transition blocks (from the `Simulink/Signal Attributes` library) to the subsystem inputs with a sample time of *Ts_speed* (execution time of the speed control loop).

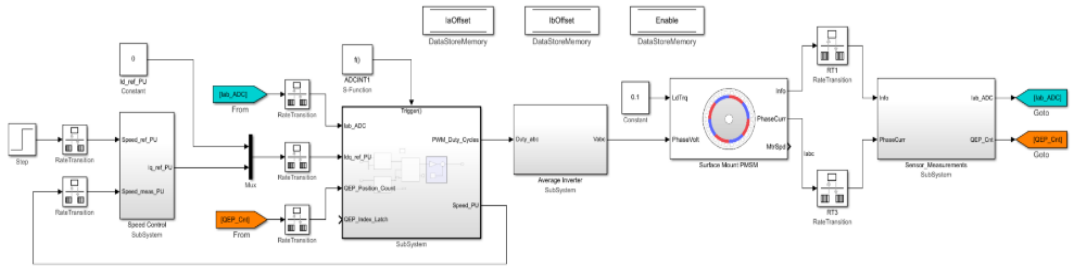


Figure 3 integrated speed controllers, current controller, and plant model subsystems.

Integrate the speed controller subsystem in figure 3 (that you created in step 2) with the integrated current controller and plant model subsystems. Connect the **Iq_ref_PU** output port of the speed controller subsystem to the current controller subsystem input port through a rate transition block. The rate transition block is needed because the two ports execute at different sample rates. This figure shows an example of the parameter settings of the Rate Transition block connected to the speed controller and the current controller subsystems.

Result Analysis

To manually tune the speed controller subsystem, provide a step input (in the range of 0.2 to 0.5 PU) to the Speed_ref_PU input in the speed controller subsystem (Speed

Control). Monitor the measured speed step response (Speed_meas_PU) and adjust the speed controller subsystem parameters to meet your control objectives.

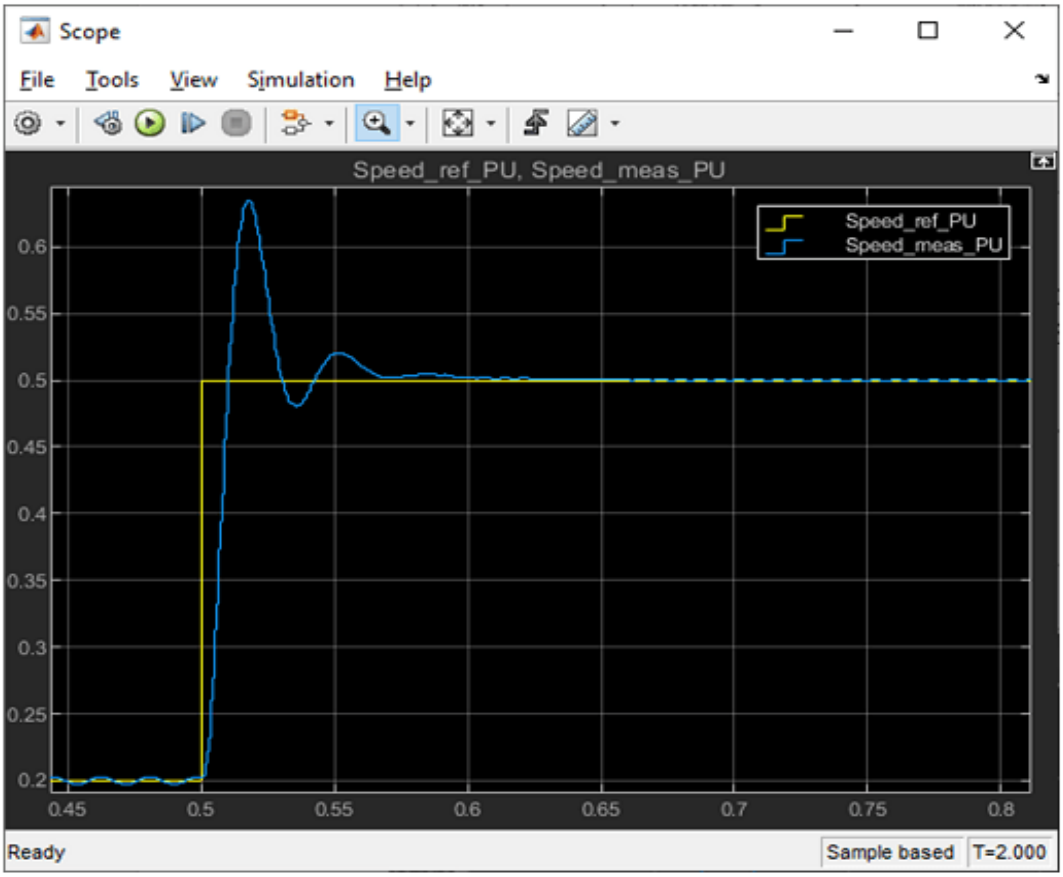


Figure 4 step response of the speed controller.

Figure 4 procedure shows a method to implement speed control for a PMSM in simulation. Run the simulation and analyze the controller performance.

You can generate C code from this control algorithm using Embedded Coder®. In addition, you can deploy this code and the hardware drivers to the target hardware.

Conclusion

In conclusion, this research has investigated the enhancement of automated guided vehicle (AGV) speed reduction control through the integration of expert systems. Through a combination of theoretical analysis, system design, implementation, and experimental validation, several key findings and contributions have been made. The integration of expert systems into AGV speed reduction control has shown promising

results in improving navigation efficiency while ensuring operational safety. By leveraging domain knowledge and logical inference mechanisms, the expert system can dynamically adjust AGV speed based on real-time sensor inputs and environmental conditions. This adaptive approach allows AGVs to navigate through complex and dynamic environments with greater precision, agility, and reliability.

The experimental evaluation has demonstrated the effectiveness of the expert system approach in enhancing AGV performance metrics such as navigation time, obstacle avoidance accuracy, and energy efficiency. Comparative studies have shown significant improvements over traditional speed control methods, highlighting the potential of expert systems to revolutionize AGV operations in industrial settings.

Recommendation

Looking ahead, future research directions may focus on optimizing the expert system parameters, enhancing real-time adaptation capabilities, and scaling the solution to larger AGV fleets and more diverse operating environments. Additionally, exploring advanced AI techniques, such as machine learning and reinforcement learning, could further enhance the intelligence and autonomy of AGV systems.

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