Universidad Politécnica de Tulancingo

Informe Trimestral de Actividades

Dirección de Planeación, Programación y Evaluación

Trimestre	octubre-diciembre	Fecha	8 de diciembre de 2023

Componente	3. Investigación	Actividad	3.1 Productos de Investigación
Nombre del Indicador	Porcentaje de productos de investigación científica y tecnológica realizados		
Resumen Narrativo	3.1 Realización de productos de investigación científica y tecnológica de educación superior		
Supuestos	Los investigadores participan en las convocatorias para el desarrollo de proyectos de investigación científica y tecnológica.		
Medios de Verificación	Informe trimestral de productos de investigación científica y tecnológica realizados generado y ubicado en la Dirección de Investigación y Posgrado adscrito a la Secretaria Académica de la Universidad Politécnica de Tulancingo.		

Metas Trimestrales			
Programada	4	Alcanzada	4

Descripción de Actividades

Durante el trimestre octubre - diciembre 2023, se programaron 4 metas, que derivan en 4 productos de investigación. Estos productos de investigación (artículos de corte científico tecnológico o publicaciones de artículo como capítulo de libro de investigación colaborativa a nivel Latinoamérica) fueron presentados en revistas de corte internacional o en libros con relevancia a nivel internacional y son los siguientes:

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Desarrollo de Actividades y Evidencia Fotográfica

1.-Nombre del artículo: **Robust Motion Control for Aerial Robotic Systems in Monitoring Applications**

2.-Nombre del artículo: **Tracking Control Approach of Speed Profiles of Induction Motors used in Electric Vehicles**

3.-Nombre del artículo: **Mobile Manipulator Robot Path–Tracking Control for Integration in Smart Energy Grid Applications**

4.-Nombre del artículo: **Enhanced Output Tracking Control for Direct Current Electric Motor Systems Using Bio-Inspired Optimization**

1.-Nombre del artículo: **Robust Motion Control for Aerial Robotic Systems in Monitoring Applications**

Autores: ***Hugo Yáñez-Badillo, **Francisco Beltrán-Carbajal, **Irvin López-García, ***Daniel Galván- Pérez, * Alejandro Álvarez-Diaz, **José Luis Hernández -Ávila, **** Iván Rivas-Cambero**

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Robust Motion Control for Aerial Robotic Systems in Monitoring Applications

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***Abstract*—Mobile robots usage have allowed a properly performance of complex tasks in various fields without human intervention. Unmanned aerial robots have been successfully used in monitoring applications within indoor and outdoor scenarios. The main contribution of this research is to introduce a novel robust neural sliding-mode control for a four-rotor aerial robot in monitoring tasks. To verify the effectiveness of the proposed motion control scheme, it is considered a simulation scenario where the vehicle is subjected to unknown disturbances while the robot is flying towards different operation points, as required in real-time monitoring applications. Bézier polynomials are suitably integrated in the motion control scheme to smooth the system motion. Additional case study is also included where B-spline artificial neural networks are efficiently introduced for improving the system performance while maintaining its stability despite random undesired abrupt position changes due to the induced forces by wind. Finally, to highlight the effectiveness of the introduced controller, the vehicle is simulated in a virtual scenario where a rapidly exploring random tree (RRT) algorithm is implemented for determining the best path in a constrained space. This preliminary results effectively promote the development of cyber-physical systems for monitoring application management, as required in the electric power systems.**

***Index Terms*—Aerial Robotic System, Motion Control, Neural Sliding Modes, Monitoring Applications.**

I. Introduction

The quadrotor is an underactuated system that presents a highly nonlinear dynamic behaviour and is capable to hovering and vertical take-off and landing (VTOL). Those capabilities have attracted the researchers attention from different technological fields. Notwithstanding, uncertainty, parasitic and unmodeled dynamics, external disturbances, difficult the operation and flight of the quadrotor system. Thus, effective automatic control schemes must be proposed for ensuring the system functioning even in hostile environments. This kind of vehicles have successfully implemented in monitoring applications since can gather detailed target data from different perspectives, any physical contact with the target is unnecessary and they can they reach inaccessible areas in hostile environments.

One of the most relevant proposed theories within the automatic control is the sliding modes theory, which have been effectively employed for controlling complex high-order nonlinear dynamic systems [1]. The main drawback for implementing sliding modes based-control is that high-frequency oscillations with finite amplitude (chattering) are present in the control inputs, since it is required the design of a sliding surface and the action of discontinuous signals for ensuring

2.-Nombre del artículo: **Tracking Control Approach of Speed Profiles of Induction Motors used in Electric Vehicles**

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Tracking Control Approach of Speed Profiles of Induction Motors used in Electric Vehicles

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***Abstract*—Electromobility is an area in growing development that seeks to make the transport sector more efficient through electric vehicles with the development of new automatic control technologies and the incorporation of renewable energies. In this context, efficient speed control in electric vehicles is essential, and applicable in vehicles powered by an electric motor, this allows the vehicle to be brought from a state of rest to an operating condition desired by the user in a controlled manner. For following planned speed trajectories for the operation of a vehicle powered by a three-phase induction motor a control strategy is presented in this paper. The results of the computer simulation verify the effectiveness in the implementation of the controller in an electric vehicle considering its dynamics, its systems of power transmission and a three-phase induction motor.**

***Index Terms*—Automatic Motor Control, Bezier Curves, Electric Vehicles, Electromobility, Induction Motor.**

I. Introduction

New technologies have been developed due to the growing demand for electric and hybrid vehicles [1]. Electric vehicles in the transportation sector typically incorporate at least one electric motor, which serves as the primary component for converting electromechanical energy for vehicle propulsion [2]. The power transmission system in electric transportation necessitates a wide operating speed range and high efficiency in torque and speed generation by the motor [1]. In most electric vehicles, an electric motor is commonly connected to a reduction gear (gearbox) and a mechanical differential [3].Induction motors are an attractive option for electric vehicle applications due to their robustness, cost-effectiveness, low maintenance requirements, and well-established technology [4]. When analyzing motor options for electric vehicles, both permanent magnet motors and induction motors are considered, with a focus on achieving high efficiency [5].

A fundamental challenge is presented by the displacement control of induction motors for high dynamic performance applications. This is attributed to the non-linear dynamics that describe the conversion of electrical energy into mechanical energy [6]. Furthermore, the occurrence of unknown external loads and variations is possible during the operation of the induction motor. Efficient regulation of various voltage control inputs and several outputs, such as stance, speed, magnetic flux, and torque, is achieved by the dynamic model of the induction motor [7]. Consequently, the use of induction motors is limited to industries where speed regulation is not required. However, the increasing technological development of recent years in areas of understanding such as power electronics and superior construction techniques for microprocessors, allow the use of controllers to regulate the speed of induction motors [8]. In this context, control strategies relying on Proportional, Integral, and Derivative (PID) controllers are the most commonly employed in the industry. However, traditional controllers have the possibility of exposing constraints to obtain universally robust performance in the presence of uncertainty and exogenous perturbations that vary with age, requiring a precise understanding of the mathematical model and the boundaries of the nonlinear dynamical system [9].

In recent years, various inquiries have been made in relation to trajectory tracking. The proposed control approaches are based primarily on electronic power steering (EPS), active steering system (AFS) or steering by system (SWB) [10]. Although, there are some applications of these engines in which specific drivers were created for all of them [11]. On the other hand, there is the application of specific controllers for this type of motors such as the Fuzzy controller [12] or Fuzzy based on observers [6], there are also controllers directly applied to the axial flow as field oriented control [13] or adding optimization in genetic algorithms [14]. However, 3.-Nombre del artículo: **Mobile Manipulator Robot Path–Tracking Control for Integration in Smart Energy Grid Applications**

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Mobile Manipulator Robot Path–Tracking Control for Integration in Smart Energy Grid Applications

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Abstract—**Integrating robotics into modern power grids has become increasingly popular. Mobile robotic systems can play an important role in smart energy grids by performing different tasks such as inspection, monitoring, maintenance, and repair of electrical networks. In this sense, integrating mobile robots in smart grid applications offers a series of benefits, such as reducing the time and cost of maintenance tasks and improving the safety and reliability of smart energy grids. However, robust motion control schemes are required to reject disturbances to ensure these robots can effectively perform their assignments. This paper presents a robust output feedback–based path–tracking control strategy for mobile manipulation systems. The proposed approach uses only position measurements to compute the control inputs required to maintain robotic systems on the expected course, despite of unknown and unexpected disruptions. Computational simulation experiments demonstrate the efficacy of the presented control scheme in a mobile manipulation robotic system subjected to unpredictable time–varying disturbances.**

Keywords—***Mobile Manipulation Robotic Systems, Robust Path–Tracking Control, Smart Energy Grid Applications.***

I. Introduction

Smart energy grids are an innovative combination of information and communication technologies with electrical infrastructure designed to improve energy supply efficiency, safety, and sustainability [1]. Some aspects that characterize these grids are distributed renewable energy generation, active demand management, and bidirectional communication among various agents [2]. While these systems offer many benefits, their complexity and their dynamic nature require constant monitoring and maintenance of their components, including substations, transmission lines, and generators, to ensure their smooth operation and minimize the risk of service disruptions [3]. Monitoring and maintenance activities can pose risks to technical personnel and affect service continuity, constituting a significant challenge for the energy sector [4]. To address these challenges, robotics has emerged as a promising solution to work in hazardous and hard–to–reach environments in various industrial processes, including power systems and smart energy grids. Mobile manipulation robotic systems offer a viable alternative, allowing for task automation and improving efficiency while reducing costs and avoiding operational risks in power systems and smart energy grids [5]. These robots can move through different environments, manipulate objects precisely, access to difficult or dangerous places, and perform complex operations autonomously or teleoperated, making them suitable for various applications in smart energy grids [6]. Applications that can integrate these systems include visual and/or thermographic inspection of electrical components, replacement or complete repair of damaged parts, adjustment or calibration of parameters, sampling or fluid analysis, and cleaning or obstacle removal [7].

However, the integration of robotic systems into smart energy grids requires robust control schemes guaranteeing these systems' safe and effective operation [8]. A robust control scheme is a control scheme that maintains a correct and stable performance under different conditions, such as parameter variations, external disturbances, and model uncertainties [9]. Therefore, this article presents a motion control strategy for mobile manipulation robotic systems to improve their performance in path–tracking tasks for integration into power systems and smart energy grid applications. Path–tracking task involves making the robotic system follow some desired route or path without any temporal specifications and with minimal error, considering the motion and modeling constraints of the system [10]. In addition, the controller must ensure the proper performance of the robotic system despite the uncertainties and disturbances inherent in its operating environment. Some examples of disturbances and uncertainties include variations in the physical parameters, errors in measurement or estimation of the robotic system states, sensors or actuators signals noise or interference, changes in environmental conditions, such as lighting or temperature, static or dynamic obstacles on the route, and partial or total failures in one or more mechanical components, to mention only a few [11].

4.-Nombre del artículo: **Enhanced Output Tracking Control for Direct Current Electric Motor Systems Using Bio-Inspired Optimization**

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Article

Enhanced Output Tracking Control for Direct Current Electric Motor Systems Using Bio-Inspired Optimization

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Abstract: In this paper, an efficient output reference trajectory tracking control scheme for direct current electric motor systems based on bio-inspired optimization is proposed. The differential flatness structural property of the electric motor along with dynamic tracking error compensation is suitably exploited for the backstepping control design. Off-line optimal selection of control parameters, implementing bio-inspired ant colony and particle swarm optimization algorithms, is addressed by minimizing an objective function where the decision variables are the tracking error and control input effort. A novel adaptive version of the control approach based on B-spline artificial neural networks is provided as well. The introduced flat output feedback tracking control design approach can be further extended for other differentially flat dynamic systems. Considerably perturbed, diverse velocity and position reference trajectory tracking scenarios are developed for demonstrating the acceptable closed-loop system performance. The results prove the efficient and robust tracking of the position and velocity reference profiles planned for the operation of the controlled electric motor system under variable torque disturbances using bio-inspired optimization.

Keywords: machines; DC motors; robust control; differential flatness; backstepping control; optimization; bio-inspired algorithms

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1. Introduction

Nowadays, there is a wide range of applications and processes that demand increasingly advanced automatic systems capable of providing movement with high precision while being subjected to various unwanted and unknown external disturbances in multiple operating scenarios. A large part of these automatic systems depends on the proper control of actuation subsystems that provides to the main system the ability to perform specific regulation and trajectory tracking tasks. Direct current (DC) electric motors are ideal for a multitude of industrial and service applications where high torque and variable speed are required [1,2]. These range of applications stand from the construction of educational prototypes to the development of advanced systems where precise movements are required, such as in robots [3,4].

The development of DC motor control systems remains an active and multifaceted research field driven by several motivations. Researchers persistently endeavour to enhance the efficiency, performance, and reliability of these systems by refining control algorithms, sensor technologies, power electronics, and overall system integration to achieve heightened energy efficiency and responsiveness. Constant advancements in control theory lead

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