المؤتمر الدولي الخامس للأتمتة التطبيقية والتشخيص الصناعي

غرداية، الجزائر | 18– 20 نوفمبر 2025

CP_102 _ 153 _ 2025

Djelfa University
LAADI
Laboratoire d'Automatique Appliquée et Diagnostics Industriel

IEEE 2025 ICAAID

Ghardaïa, Algeria | 18 –20 November 2025

CERTIFICATE OF PARTICIPATION

This to certify that:

Lalia Miloudi

Affiliation: Applied Automatic Laboratory, Department of Electrical Systems Engineering, University of M ' hamed Bougara of Boumerdes, Boumerdes, Algeria

has successfully presented a paper entitled: Design of sliding mode control applied to inverted cart-pendulum for good stability performances

Co-Authored by: Alla Eddine Toubal Maamar, Oumaymah Elamri, Tassadit Benabdallah, Mourad Naidji, Abdelkader Garmat

at the IEEE 2025: 5th International Conference on Applied Automation and Industrial Diagnostics ICAAID 2025 .

The 5th International Conference on Applied Automation and Industrial Diagnostics
ICAAID 2025
18-20 November 2025
Ghardaïa, Algeria

General Chair
Prof. Ahmed Hafaifa

General Chair

IEEE Algeria Section

Electron Devices Society
Algeria Section Chapter EDS

IEEE PES Power & Energy Society
Algeria Section Chapter

pels IEEE POWER ELECTRONICS SOCIETY
Algeria Section Chapter

2025 5th International Conference on Applied Automation and Industrial Diagnostics (ICAAID)

Design of Sliding Mode Control Applied to Inverted Cart-Pendulum for Good Stability Performances

Lalia MILOUDI
Applied Automatic Laboratory Department of Electrical Systems Engineering, University of M'hamed Bougara of Boumerdes
Boumerdes, Algeria
lamiloudi@univ-boumerdes.dz

Alla Eddine TOUBAL MAAMAR
LIST Laboratory, Department of Electrical Systems Engineering, Faculty of Technology, University of M'hamed Bougara of Boumerdes
Boumerdes, Algeria
a.toubalmaamar@univ-boumerdes.dz

Oumaymah ELAMRI
Pluridisciplinary Laboratory of Research & Innovation (LPRI), École Marocaine des Sciences de l'Ingénieur (EMSI) of Casablanca
Casablanca, Morocco
O.elamri@emsi.ma

Tassadit BENABDALLAH
Applied Automatic Laboratory Department of Electrical Systems Engineering, University of M'hamed Bougara of Boumerdes
Boumerdes, Algeria
benabdallah.edu@gmail.com

Mourad NAIDJI
Laboratory of Electrical Engineering (LGE)-University of M'Sila, Department of Electrical Engineering, Badji Mokthar-Annaba University
Annaba, Algeria
mourad.naidji@univ-annaba.dz

Abdelkader GARMAT
LIST Laboratory, Department of Electrical Systems Engineering, Faculty of Technology, University of M'hamed Bougara of Boumerdes
Boumerdes, Algeria
a.garmat@univ-boumerdes.dz

***Abstract*—This paper proposes a resilient sliding mode control (SMC) strategy for the stabilization of a cart-pendulum system, tackling significant issues in nonlinear control, including parametric uncertainties and external disturbances. The suggested solution uses a two-step process: first, an open-loop energy-based swing-up to lift the pendulum, and then a closed-loop SMC phase to keep it stable. The designed controller uses a saturation function to reduce chattering, which is different from methods that depend on linearized models or complicated gain tuning. The simulation results show that the accuracy is very high, with settling times of about 5 seconds for the pendulum angle and 7 seconds for the cart position. The controller works well even when the system mass and disturbances change by 10%, as long as the cart can only move ±0.5 m and the control forces can only be ±10 N. Stability is reached from the most unfavorable initial condition, the pendulum's downward-hanging position, with a steady-state error of under 1% in essential state variables. This work offers a computationally efficient and adaptive solution, appropriate for real-time applications in robotics and aerospace where resilience to nonlinear dynamics and uncertainty is essential.**

Keywords*—*Dynamic systems, Inverted pendulum, Nonlinear control, Sliding mode control, Stability.

I. Introduction

Over the past decades, the dynamic systems have been the focus of extensive research activities in various fields, classified according to their type (linear, nonlinear, continuous, discrete, deterministic, and stochastic) [1]-[3]. The dynamic systems natures are: Physics (such as pendulum and spring-mass-damper systems); Biological systems as model for predator and prey (Lotka-Volterra); Computer science; Chaotic systems, and other engineering systems [4], [5]. In designing dynamic systems, the control theory has never ceased to amaze researchers with its extremely complicated challenges, particularly in stabilizing unstable nonlinear systems [6]. Among these, the inverted pendulum is one of the traditional problems that appear to be easy to design but notoriously hard to control [7]. The researchers in the book [8] introduced a design of an augmented Fractional Order Proportional-Integral-Derivative (*FOPID*) controller for cart inverted pendulum system. *FOPID* controllers are superior but difficult to tune. The article proposes a simpler, computationally intensive alternative with the use of Teaching Learning-Based Optimization (*TLBO*) for linear/nonlinear systems with stability and robustness proof. H. Choe et al. [9] proposed the application of a cascade control scheme for cart inverted pendulum position tracking using T-S fuzzy model-based linear active disturbance rejection controller (*LADRC*). The T-S fuzzy-based *LADRC* incorporates nonlinear dynamics to alleviate observer load and enhance performance. Inverted pendulum on cart simulations demonstrate improved disturbance rejection, transient response, and robustness compared to *PID*. A.V. Pesterev and Y.V. Morozov [10] have proposed the stabilization analysis of an inverted pendulum on a cart. New control law is suggested based on the realization of a second-order reference system. Apart from this, M. Rani and S.S. Kamlu [11] discussed optimal Linear Quadratic Gaussian (*LQG*) controller design of inverted pendulum systems using an integrated approach. *LQG* control outperforms *PID* and Linear Quadratic Regulator (*LQR*) in stabilizing cart-pendulum systems, noise, and disturbances effectively. MATLAB simulations demonstrate its efficacy for nonlinear operations using linearized models. De la Cruz-Alejo et al. [12] proposed an inverted pendulum with three control techniques-based decision strategy. In the paper, how the parameters' changes affect the control of an inverted pendulum is examined with special focus on the fact that more uncertainty causes undesirable system responses. Moreover, the paper gives some useful insights into choosing suitable control methods for uncertain, nonlinear systems such as the inverted pendulum, in which adaptive and intelligent control emerges superior to conventional *PID* in respect of responsiveness and stability. S. Shreedharan et al. [13] solved the problem of stabilizing an inverted pendulum, a highly nonlinear system, by introducing a new voltage-to-dynamics mapping technique in order to improve accuracy for control. This research presents a successful, scalable method of stabilizing nonlinear systems, with applications in robotics, aerospace, and industrial automation. Imagine a pole balanced perilously atop a rolling cart: a small error sends it crashing to the ground. But studying this system is not merely academic; it's the answer to rocket stabilization, robot stabilizing, and even autonomous car technology [14]. Real-world systems such as segway-type transportation or rocket launching share the same general problem: stability with minimal control effort. Techniques such as *PID* controllers suffice well when the pendulum is virtually upright. But what if it begins in the most adverse position, directly downwards ? Linearized models are lacking, and even sophisticated methods such as neural networks or fuzzy logic are struggling with computational cost and agony calibrations [15]. Enter Sliding Mode Control (*SMC*), consider a control algorithm so robust that it can drive through abrupt disturbances, such as a gust of wind or spontaneous weight transfer without breaking a sweat. *SMC* does just that, guiding the system onto a pre-specified stable path and maintaining it so. But it's not flawless. The classic version suffers from "chattering", a rapid, jarring control action that can wear out actuators. Our work tackles this by refining *SMC* to smooth out these harsh movements while preserving its unbeatable stability.

In this paper, we discusses the use of *SMC* technique to obtain high-performances control of the cart-pendulum system. Our choice of this control method is motivated by its robustness, and reliable performances [16], [17]. For these reasons, our goal is the design of controller that increases accuracy and reduces the time of convergence, moving the pendulum of the most unfavorable initial condition, the descending equilibrium position, while also considering the viscous friction of the cart. Unlike the three-step approach, our method is implemented in two steps, and robustness against system uncertainties will be evaluated to demonstrate the effectiveness of the control strategy.

II. System Configuration and Operating Principle

As illustrated in Fig. 1, the system is controlled by a single input, the sideways force generated by the *DC* motor to move the cart. We measure two key responses: how far the cart moves along its path, and how much the pendulum leans away from straight up. The system consists of a pendulum with $2l$ length and mass m, suspended on a cart of mass M. The only friction considered in this model is the viscous friction associated with the cart's movement, represented by the coefficient B, while the viscous friction of the pendulum is neglected. The acceleration due to gravity is represented as g. The system envisioned needs to satisfy two significant initial conditions:

(1) Total rotation capacity: The arm must have a capacity to rotate 360° in order to characterize all possible initial conditions.

(2) Correct deflection of the cart: The system should permit adequate horizontal motion, especially from the stable downward equilibrium of the pendulum, worst case starting situation.

By employing the Euler-Lagrange technique, the equations of dynamics governing the system are obtained as follows:

$$\begin{cases} (M+m)\ddot{x} + f\,\dot{x} + ml(\cos(\theta)\ddot{\theta} - \sin(\theta)(\dot{\theta})^2) = F \\ \frac{4}{3}ml^2\ddot{\theta} + ml(\cos(\theta)\ddot{x} - g\sin(\theta) = 0 \end{cases} \tag{1}$$

The state-space formulation of equations (1) can be expressed as follows:

$$X = \begin{bmatrix} x_1 & x_2 & x_3 & x_4 \end{bmatrix}^T = \begin{bmatrix} \theta & \dot{\theta} & x & \dot{x} \end{bmatrix}^T,$$

$$\dot{X} = \begin{bmatrix} \dot{x}_1 & \dot{x}_2 & \dot{x}_3 & \dot{x}_4 \end{bmatrix}^T = \begin{bmatrix} x_2 & \ddot{\theta} & x_4 & \ddot{x} \end{bmatrix}^T$$

Where:

$$\begin{cases} \ddot{\theta} = h_1 - h_2\frac{f_1}{f_2} - \frac{h_2}{f_2}u \\ \ddot{x} = \frac{f_1 + u}{f_2} \end{cases} \tag{2}$$

The coefficients h_1, h_2, f_1, f_2, and u can be calculated as:

$$\begin{cases} h_1 = \frac{3}{4l}g\sin(\theta) \\ h_2 = \frac{3}{4l}\cos(\theta) \\ f_1 = m(l\sin(\theta)\dot{\theta}^2 - \frac{3}{8}g\sin(2\theta)) - f\,\dot{x} \\ f_2 = M + m(1 - \frac{3}{4}\cos^2(\theta)) \\ u = F \end{cases} \tag{3}$$

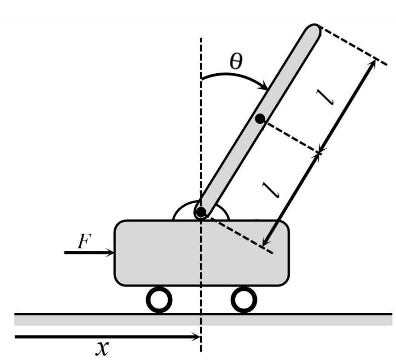

Fig. 1. Schematic of the suggested Cart-Pendulum system.

III. SLIDING MODE CONTROL IMPLEMENTATION

Sliding mode control, also known as variable structures control (VSC). Been extensively developed and optimized in control systems engineering over the past five years. With advances in contemporary technology, SMC has been established to be a robust and effective approach to control [18]. The powerful technique is built with a systematic framework through sliding surfaces. Additionally, on the basis of Lyapunov's stability theorem. One of its primary benefits is that it can handle system uncertainties and exterior diseases to maintain system stability based on its invariance properties in sliding regimes. Moreover, SMC has advantages like alleviating system demands and design flexibility [19].

As a nonlinear control technique, *SMC* employs a high-frequency switching control law to guide the state's trajectory of a nonlinear system on a predefined sliding surface in the state space and keep it there. This surface, known as a sliding or switching surface, defines system behavior when states reach it. When the system operates in sliding mode, its dynamics become independent of uncertainties and external disorders provided that sliding mode conditions are met.

According to the sliding mode theory, a state is classified as a sliding when its velocity vector around the switching surface pushes the system towards that surface [20]. The design of *SMC* can typically be structured in three major steps: selecting a suitable sliding surface, establishing the conditions for its existence, and formulating the control law.

A. Sliding Surface Selection

Choosing the sliding surface means figuring out both how many there need to be and what shape they need to be in. These factors are determined by the particular application and the intended control goals. For a system represented by the following state equation:

$$\dot{X}(t) = A(X,t) + B(X,t)u(t) \tag{4}$$

It is essential to define m sliding surfaces, where m corresponds to the dimension of the state vector. Regarding the surface formulation, various linear and nonlinear forms can be considered. Among the linear options, the Slotting surface is commonly used and is expressed as follows:

$$S(X) = \left(\frac{d}{dt} + \lambda_X\right)^{r-1} e \tag{5}$$

Where: X: is state vector. $S(X) = 0$: A linear differential equation whose only solution is ($e = 0$). e: The error ($e = Y - Y_d$). λ_S: is a constant parameter with a strictly positive value. And, r: Relative degree of the system.

B. Conditions of Convergence and Existence

The terms of convergence and existence establish the parameters that allow the dynamic system to reach the sliding surface and not be affected by disorders. Several factors must be considered to ensure convergence, ensuring that the system maintains the operation in sliding mode. The necessary conditions for this are:

$$\begin{cases} \dot{S}(X) > 0 & if \quad S(X) < 0 \\ \dot{S}(X) < 0 & if \quad S(X) > 0 \end{cases} \tag{6}$$

C. Law Control Calculation

Obtaining control of the sliding mode requires the use of a discontinuous control law. The sliding surface must be designed to ensure attractiveness. Although discontinuous control is necessary, a continuous component can be incorporated to minimize the breadth of the discontinuous term as much as desired. In the presence of disorders, the main role of the discontinuous component is to enforce the conditions necessary for the attractiveness of the system.

$$u = u_{eq} + u_n \tag{7}$$

The term u_{eq} is responsible for keeping the controlled variable on the sliding surface $S(X) = 0$. It is obtained by setting the surface equation to zero, leading to $\dot{S}(X) = 0$. Alternatively, it can be interpreted as the average control value during the rapid switching between u_{max} and u_{min}. The discontinuous component u_n is designed to satisfy the convergence condition, ensuring that the system reaches and remains on the sliding surface. In general:

$$\begin{cases} u_{eq} = -\left(\dfrac{\partial S}{\partial X} B(X,t)\right)^{-1} . \dfrac{\partial S}{\partial X} . A(X,t) \\ u_n = K_S sign(S(X,t)) \end{cases} \tag{8}$$

Where, the symbol *sign*() represents a sign function.

As described in the introduction, in this study the control of the sliding mode will be implemented in two stages, each requiring the selection of a distinct sliding surface. The purpose of the first surface is to make it easier for the pendulum to spin and move toward the unstable equilibrium point. The second surface positions the cart at the desired location and guarantees that the pendulum stays stable at this equilibrium point.

D. First Step: Swing-up

The cart is directed to follow a sinusoidal trajectory during this phase. In order to give the pendulum the energy it needs to swing upward and get closer to the vertical equilibrium position, this particular trajectory was chosen. The cart's motion is managed to keep it inside the rail's horizontal bounds. This step's sliding surface is described as follows:

$$S_1 = \lambda(x_3 - x_{3d}) + x_4 \tag{9}$$

At this point, the pendulum is uncontrolled since the *SMC* is only applied to the cart's states.

E. The Second Step: Stabilization

At this stage, we ensure that all system states converge to their desired values. As a result, the pendulum stabilizes at its unstable equilibrium point ($x_1 = x_2 = 0$), while the cart reaches and maintains its target position ($x_3 = x_{3d}$, $x_4 = 0$). The system is designed using linear state feedback centered on the unstable equilibrium point, as it operates in the linear region.

$$S_2 = KX \tag{10}$$

Using pole placement techniques, the feedback gain vector K is found and applied to the linear approximation of the system close to its unstable equilibrium point. In this mode of operation, the system operates in a closed-loop structure in which the *SMC* indirectly stabilizes the behavior of the pendulum while directly controlling the motion of the cart.

A saturation function, sat(), is used in place of the control law's discontinuous sign function to lessen the chattering effect frequently connected to sliding mode control. Consequently, the control law for both steps can be written as follows:

$$u = -\left(\frac{\partial S}{\partial X}B(X,t)\right)^{-1}.\frac{\partial S}{\partial X}.A(X,t) + K_S sat(S(X,t)) \quad (11)$$

IV. Results Discussion

The initial conditions of the system and the parameters are listed in Table II. The system consists of a pendulum with $2l$ and of the mass m, suspended from a cart of mass M.

TABLE II. The system parameters

Symbol	Quantity	Value
l	Length of the pendulum	0.25 *meter*
m	Mass of the pendulum	0.1 *Kg*
M	Mass of the cart	1 *Kg*
g	The gravitational acceleration	9.8 m/s^2
f	Accretion mass rate	0.5 *Kg/s*
x	The rail length	1 *meter*

The cart motion needs to keep the pendulum in its vertical, unstable equilibrium position and within tight limits of travel. Specifically:

1) The cart displacement needs to stay within ± 0.5 meters of reference.

2) The control force used needs to be no greater than ± 10 Newton.

These constraints ensure the balance of the pendulum without extreme motion or over application of force. We initiate the system in the condition when the pendulum is at the bottom stable position and the cart at the center position along the rail, as already established. i.e. $X_0^T = [\pi, 0, 0, 0]$.

A. System responses test

Fig. 2 and Fig. 3 illustrate the simulated pole angle and cart position performance. The pendulum has a smooth swing-up behavior, thanks to the controlled cart oscillations.

We can observe in the first 3.84 seconds of Fig. 2 and Fig. 3, that the swing-up controller stabilizes the system dynamics. Then the stabilization controller acts, successfully:

1) *Balancing the pendulum in its inverted.*
2) *Positioning the cart at the desired location.*
3) *Maintaining all movements within specified boundaries.*

Notably, the cart's displacement remains well within operational limits, reaching a maximum deviation of just ±0.2 meters from the rail center. The system demonstrates stable convergence with:

✓ Pendulum (x_1) settling time: 5 seconds.
✓ Cart (x_3) settling time: 7 seconds.

The phase plans for the pendulum sub-system and the cart sub-system are displayed in Fig. 4 and Fig. 5, respectively. The outcomes validate the stability of the system by demonstrating the dynamic of these two subsystems' tolerance and the convergence of all states to zero.

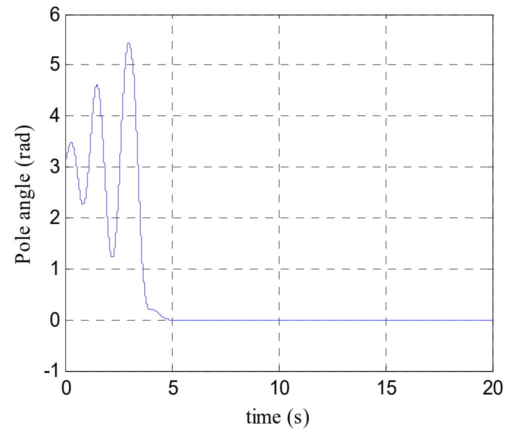

Fig. 2. The angular position response of the pendulum.

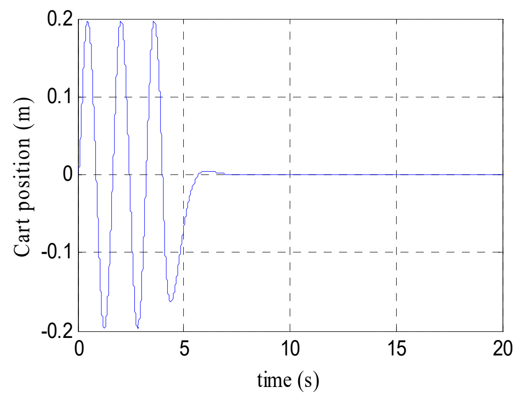

Fig. 3. Cart displacement response.

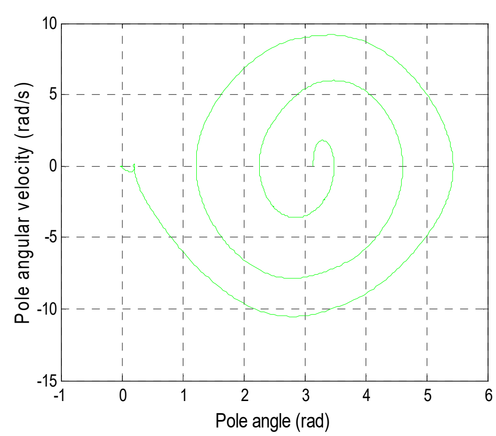

Fig. 4. Phase plane of the pendulum's dynamics.

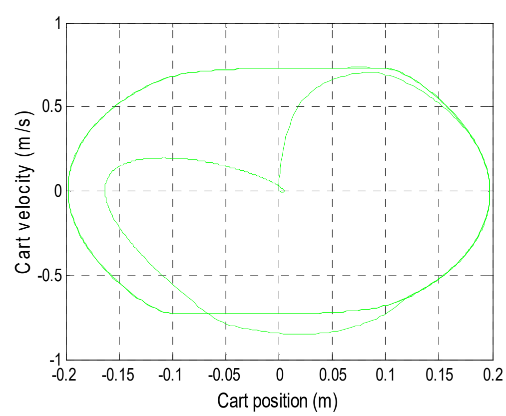

Fig. 5. Phase plane of the cart's dynamics.

The results of the sliding surface and control action simulations are presented in Fig. 6 and Fig. 7, respectively. The sliding surface in Fig. 6 seems to be stable and converges to zero, or the system states' convergence to the intended states. In Fig. 7, the control action looks inactive, no chatter, and practically achievable.

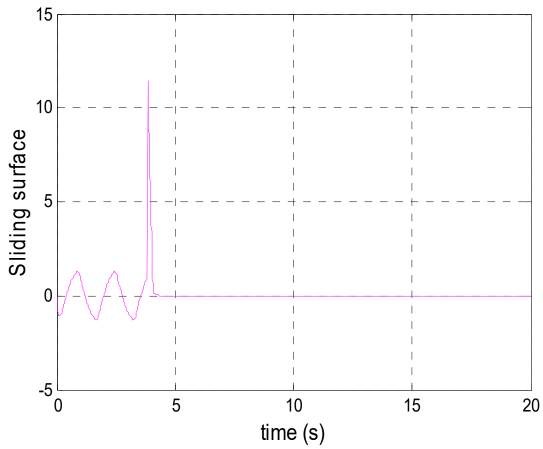

Fig. 6. Sliding surface response.

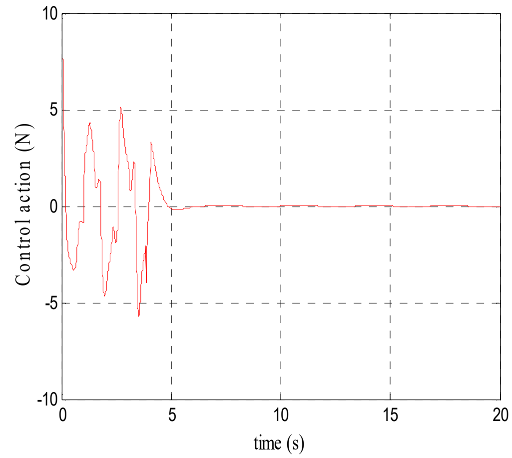

Fig. 7. Control input response.

B. *Test of system robustness and performances*

To evaluate the controller's robustness and performance, we introduced a 10% parametric error in both the pole mass and the cart mass. The synthesized control was applied to the simulated model, followed by deliberate disturbances: a random perturbation on the pendulum at 10 seconds and another on the cart at 13 seconds. The resulting behavior is illustrated in Fig. 8.

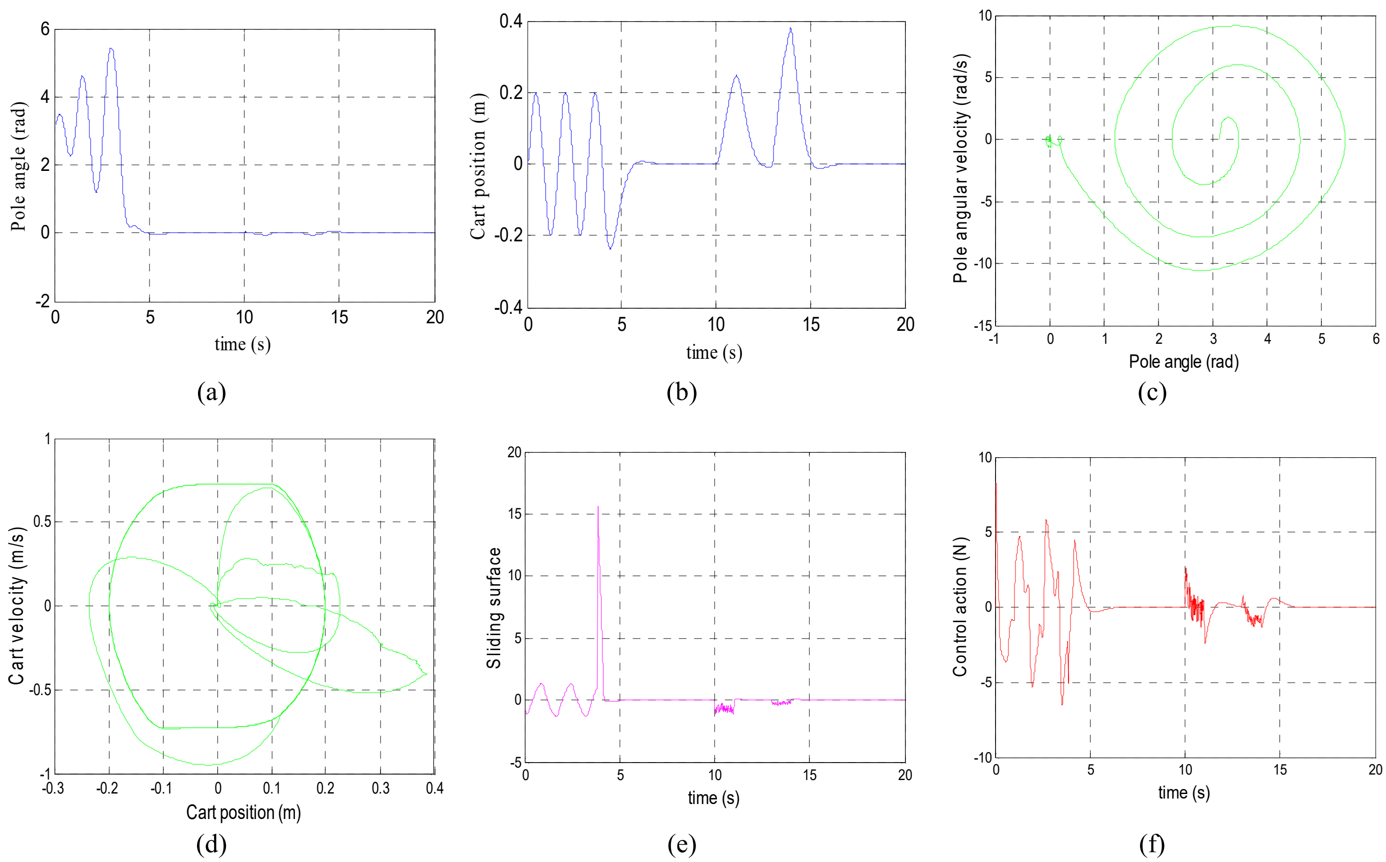

Fig. 8. Results of system robustness and performances test. (a) Response of pendulum angular position, (b) Response of cart displacement, (c) Phase plane of the pendulum dynamic, (d) Phase Plane of the card dynamic, (e) Response of sliding surface, (f) Response of the control input.

The outcomes show that even in the face of model uncertainties, the controller maintains its resilience. Some important observations are that the sliding surface converges smoothly to zero and that the pendulum and cart stabilize within regular settling times of five and seven seconds, respectively. Effective tolerance is demonstrated by the control action staying within predetermined bounds.

The system reacts to disturbances at 10 and 13 seconds by causing only minor oscillations in the pendulum close to its upright position and small cart displacements (0.26m at 10s and 0.38m at 13s). After each disturbance passes, the controller swiftly adjusts for it, restoring stability in two seconds with the least amount of energy. Interestingly, during the process, the cart's displacement remains well within the designated bounds.

V. CONCLUSION

The goal of this study is to swing and stabilize the inverted pendulum in a cart with only sliding mode control, but with a more sophisticated approach that yields noticeably better outcomes. Blaming the viscous friction of the cart, the pendulum starts from the most difficult initial condition, the descending equilibrium position. We use a saturation function as a continuous substitute for the discontinuous component in order to lessen the chatter that results from the sliding mode control's discontinuous nature, which can have a detrimental effect on actuators.

Simulation results confirmed the strategy's correctness, robustness, and performance implemented and proved its feasibility. The system has a bounded and energy-saving input and fully stabilizes in state with satisfactory dynamics, excellent resolution time, and high accuracy. In addition, displacement of the cart remained within the rail limits. The robustness of the suggested nonlinear control technique, where the proper choice of the appropriate sliding surface is important, is further reaffirmed by the results achieved even with uncertainties and external disorders in the parameters.

This work is a stepping stone for further enhancement, like adding an observer and applying the method to an actual system with inverted pendulum dynamics like robotic systems.

REFERENCES

[1] S. Bajpai and A. Sameer, “The dynamics of uncertainty: a systematic review of non-linear dynamical systems in decision-making,” *Nonlinear Dyn.*, 2025, doi: 10.1007/s11071-025-11180-6.

[2] W. Hu, Q. Zhu, and K. Ding, “Stochastic finite-time stability and stabilization for stochastic nonlinear systems with impulse effects,” *Eur. J. Control*, no. 100904, p. 100904, 2023, doi: 10.1016/j.ejcon.2023.100904.

[3] K. Kyamakya, W. Mathis, R. Stoop, J. C. Chedjou, and Z. Li, Eds., Recent advances in nonlinear dynamics and synchronization: With selected applications in electrical engineering, neurocomputing, and transportation, 1st ed. Cham, Switzerland: Springer, 2017, doi: 10.1007/978-3-319-58996-1

[4] B. Lakhlani and H. Yadav, “Development and analysis of an experimental setup of spring – mass – damper system,” *Procedia Eng.*, vol. 173, pp. 1808–1815, 2017, doi: 10.1016/j.proeng.2016.12.223.

[5] R. E. A. van Emmerik, S. W. Ducharme, A. C. Amado, and J. Hamill, “Comparing dynamical systems concepts and techniques for biomechanical analysis,” *J. Sport Health Sci.*, vol. 5, no. 1, pp. 3–13, 2016, doi: 10.1016/j.jshs.2016.01.013.

[6] O. Elamri, A. E. Toubal Maamar, A. Oukassi, and L. El Bahir, “Nonlinear backstepping controller for current control of grid-connected five-level inverter,” *Rev. Politéc.*, vol. 54, no. 2, pp. 85–96, 2024, doi:10.33333/rp.vol54n2.08.

[7] M. Waszak and R. Langowski, “An automatic self-tuning control system design for an inverted pendulum,” *IEEE Access*, vol. 8, pp. 26726–26738, 2020, doi: 10.1109/ACCESS.2020.2971788.

[8] B. Dey, S. K. Pandey, and A. Sengupta, “Design of modified fractional order PID controller for cart inverted pendulum system,” *Int. J. Dynam. Control*, vol. 13, no. 4, Apr. 2025, doi: 10.1007/s40435-025-01643-4.

[9] H. Choe, K. Jang, K. Ham, and C. Kang, “A cascade control scheme with T-S fuzzy model-assisted linear active disturbance rejection controller for position tracking of cart inverted pendulum,” *Int. J. Dynam. Control*, vol. 13, no. 2, 2025, doi: 10.1007/s40435-025-01595-9.

[10] A. V. Pesterev and Yu. V. Morozov, “Stabilization of a Cart with Inverted Pendulum,” *Autom Remote Control*, vol. 83, no. 1, pp. 78–91, Jan. 2022, doi: 10.1134/s0005117922010064.

[11] M. Rani and S. S. Kamlu, “Optimal LQG controller design for inverted pendulum systems using a comprehensive approach,” *Sci Rep*, vol. 15, no. 1, Feb. 2025, doi: 10.1038/s41598-025-85581-3.

[12] J. de la Cruz-Alejo, H. Beatriz-Cuellar, I. C. A. Guillermo, and A. M. Ortega, “A decision-making approach on control techniques for an inverted pendulum based on, neuro-fuzzy, indirect adaptive and PID controllers,” *Discov Appl Sci*, vol. 6, no. 5, 2024, doi: 10.1007/s42452-024-05921-2.

[13] S. Shreedharan, V. Ravikumar, and S. K. Mahadevan, “Design and control of real-time inverted pendulum system with force-voltage parameter correlation,” *Int. J. Dynam. Control*, vol. 9, no. 4, pp. 1672–1680, Feb. 2021, doi: 10.1007/s40435-020-00753-5.

[14] U. Onen, “Model-free controller design for nonlinear underactuated systems with uncertainties and disturbances by using extended state observer based chattering-free sliding mode control,” *IEEE Access*, vol. 11, pp. 2875–2885, 2023, doi: 10.1109/ACCESS.2023.3234864.

[15] M. S. Mahmoud, R. A. A. Saleh, and A. Ma’arif, “Robust sliding-mode control for Inverted Pendulum system,” *International Journal of Robotics and Control Systems*, vol. 2, no. 2, pp. 230–239, 2022, doi: 10.31763/ijrcs.v2i2.594.

[16] S. Irfan, A. Mehmood, M. T. Razzaq, and J. Iqbal, “Advanced sliding mode control techniques for Inverted Pendulum: Modelling and simulation,” *Engineering Science and Technology, an International Journal*, vol. 21, no. 4, pp. 753–759, Aug. 2018, doi: 10.1016/j.jestch.2018.06.010.

[17] S. Zeghlache, M. Z. Ghellab, A. Djerioui, B. Bouderah, and M. F. Benkhoris, “Adaptive fuzzy fast terminal sliding mode control for inverted pendulum-cart system with actuator faults,” *Mathematics and Computers in Simulation*, vol. 210, pp. 207–234, Aug. 2023, doi: 10.1016/j.matcom.2023.03.005.

[18] Y. Li, H. Zhang, X. Xie, and J. Xia, “Stability analysis of a cart-pendulum model with variable convergence rate: A sliding mode control approach for impulsive stochastic systems,” *Chaos Solitons Fractals*, vol. 175, no. 114044, p. 114044, 2023, doi: 10.1016/j.chaos.2023.114044.

[19] J. Liu, Z. Zhao, and X. Jin, “Adaptive Fixed-Time Sliding-Mode Trajectory Tracking Control of a Cart-Pendulum Robot Against Actuator Attacks,” *Lecture Notes in Computer Science. Springer Nature Singapore*, pp. 119–129, 2024, doi: 10.1007/978-981-97-5675-9_11.

[20] M. Menebo Madebo, "Neuro-Fuzzy-Based Adaptive Sliding Mode Control of Quadrotor UAV in the Presence of Matched and Unmatched Uncertainties," in *IEEE Access*, vol. 12, pp. 117745-117760, 2024, doi: 10.1109/ACCESS.2024.3447474.

Program

18/ 11 / 2025

IEEE 2025 : The 5th International Conference on Applied Automation and Industrial Diagnostics – **ICAAID 2025 -**
Ghardaïa, Algeria | 18-20 November 2025

8 h – 9 h 00	**Registration**
9 h 00 – 09 h 45	**Opening Ceremony (Conference room)** **Prof. Ilyes Bensaci** (Rector of Ghardaïa University) **, Prof. El Hadj Ailam** (Rector of Djelfa University)
09 h 45 – 10 h 45	**Plenary Session 1** **Fast Electric Vehicles Charging Stations Infrastructure, Control, and Grid Interaction** **Professor Haitham A Abu-Rub** College of Science and Engineering, Hamad Bin Khalifa University, Qatar **Chair : Prof. Said Drid**
11 h 15 – 11 h 30	**Coffee break**
11 h 30 – 12 h 30	**Plenary Session 2** **Rethinking Grid Resilience: The Iberian Wake-Up Call** **Professor Dr. Sertac Bayhan** College of Science and Engineering, Hamad Bin Khalifa University, Qatar **Chair : Prof. Abdellah Kouzou**

Program

IEEE 2025 : The 5th International Conference on Applied Automation and Industrial Diagnostics – **ICAAID 2025 -**

Ghardaïa, Algeria | 18-20 November 2025

18/ 11/ 2025 / Afternoon : Oral Sessions (A)

	Session 1	Session 2	Session 3
Chairs	**Dr Abdelhalim Rabehi, Dr Fayçal Chouia**	**Pror. Abdallah Zegaoui, Dr Aissa Rebai**	**Pror. A. Kaabech, Dr Mohamed Elbar**
15h35- 15h50	ID 3. Issam Attoui, Nadir Fergani, Adel Boudiaf, A Robust ML-Based diagnostic procedure for rotating machinery under varying noise, speed, and load conditions	ID 49. Kaouthar Othmani, et al., Scada-based analysis of temperature effects on wind turbine performance in hot climates	ID 96. Ahmed Chennana, et al., Enhanced rotor eccentricity faults diagnosis in three-phase induction motor based on transfer learning and machine learning techniques
15h50 - 16h05	ID 7. Chellali Benachaiba, The role of satan's influence coefficient alpha base in qudwa PV MPPT optimization – A Comparative study with IT2FL	ID 56. Djamel Eddine Boukhari, Mourad Kezai, Aleatoric uncertainty-aware deep learning for robust and interpretable facial beauty prediction	ID 101. Abdelouahab Chebbah, et al., ANFIS-PSO model optimization for predicting the output parameters of a two shaft gas turbine
16h05 - 16h20	ID 16. Wahiba Menasri, et al., Vision-localization-based control of a mobile robot a real-time approach	ID 77. Abdelkader Lichti, Seddik Rabhi, Investigation of bio-inspired hybrid approaches to improve localization in wireless sensor networks	ID 108. Achour Benchabane, Modeling and Identification of the Twin Rotor Multiple-Input Multiple-Output System (TRMS)
16h20 - 16h35	ID 31. Abderraouf Bouakkaz, Adel Lahsasna, Salim Haddad, Pv power output prediction using machine learning: an accuracy assessment based on feature pattern selection	ID 91. Abdelhamid Benchikh, et al., Improved leach protocol for energy-saving in wireless sensor networks: A review	ID 138. Kaouthar Othmani, et al., Rule-based clustering and decision tree approach for SCADA-driven early fault detection in wind turbines
16h35 - 16h50	ID 41. Elhassen Benfriha, et al., Thrust vector control of a space launch vehicle	ID 144. Fatima Bachir, Ahmed Hafaifa, Nadji Hadroug, Modeling and performance evaluation of shell and tube heat exchangers using MATLAB/Simulink	ID 151. Batoun Bachir, et al., μ-Synthesis based fault-tolerant control for improved reliability of the wind turbine
16h50 - 17h10	ID 155. Soufiane Djeribie, et al., Predictive modeling of MS5002B gas turbine global efficiency using design of experiments: A case study from hassi rmel field	ID 157. Abdelfetah Ouadah, et al., Machine learning-based remote monitoring of electric vehicle battery systems	ID 158. Abdelfetah Ouadah et al., Enhancing energy management in parallel hevs through fuzzy logic optimization: A simulation-based approach

Program

IEEE 2025 : The 5th International Conference on Applied Automation and Industrial Diagnostics – **ICAAID 2025 -**
Ghardaïa, Algeria | 18-20 November 2025

18/ 11 / 2025 : Poster Sessions

	Session 1	Session 2	Session 3
Chairs	Dr Abdelouahab Khattara, Dr Naas Charrak	Dr A. kina, Prof. Abdelrezak Gacemi	Dr M. Sellah, Dr Muhhamed Abu-Rub
15h 35-16 h00	ID 159. Mohammedi Imad Eddine, Naas Djeddaoui, Abdellah Kouzou, Said Drid, Design and evaluation of a smart home system with home assistant	ID 8. Lahcène Noureddine et al., Neuro-fuzzy controller for speed control of squirrel cage induction motor	ID 40. Miloudi L., et al., Fuzzy logic control for trajectory tracking of a differential drive mobile robot
	ID 11. Mohamed Souissi, Boubakeur Zegnini , Abdelhalim Mahdjoubi, Prediction of AC flashover voltage of glass insulator under environmental pollution using the taguchi method	ID 30. Rym khettabi, Optimization of drilling performance parameters using an experimental design approach	ID 64. Nacer Hacene, Manal Amieur, Boubekeur Mendil, Fitness-Directed Strategy Switching Particle Swarm Optimization for Global Optimization and UAV Trajectory Tracking
	ID 147. Abdelouahab Chebbah, et al., hybrid neuro-fuzzy and NARX modeling for optimization and prediction of two-shaft gas turbine performance	ID 98. Ahmed Chennana, et al., Accurate classification of multiple faults in induction motor using CNN-based features and dimensionality reduction	ID 66. Hedroug Mohamed Elamine, Bdirina El Khansa, Guesmi Kamel, Identification of a Class of Affine Nonlinear Systems by T-S Fuzzy Structure with Lyapunov based LMI Stability Analysis
	ID 169. Tarek Idris Bisker, et al., Real-Time Monitoring of Solar Titan 130 Gas Turbine Based on Vibration Modeling	ID 170. Amel Sabrine Amari, et al., Real-time monitoring of a photovoltaic power plant using fuzzy logic techniques	

Program

IEEE 2025 : The 5th International Conference on Applied Automation and Industrial Diagnostics – **ICAAID 2025 -**
Ghardaïa, Algeria | 18-20 November 2025

18/ 11 / 2025: Virtual Sessions

	Session 1	Session 2	Session 3
Chairs	**Dr Ali Teta, Pror. Amar Benaissa**	**Pror. A. Bellaouar, Dr Belgacem Bekkar**	**Prof. Salam Abudura, Dr Sidali Aissat**
13h00 - 14h15	ID 4. Nora Karkar, et al., Fuzzy logic based intelligent control for irrigation timing	ID 18. Djaber Mosbah, et al., Face recognition based on Triangle model background removal and DCT pyramid decomposition	ID 68. Lavanya M. et al., Machine learning based prediction of delamination factor (Fd) in natural kevlar fiber epoxy composites machined by abrasive water jet (AWJ)
13h15 - 13h30	ID 12. Laid Sehili, Hamaidi Ouarda, Intelligent PID Based model-free control for energy-efficient speed regulation of electric vehicles	ID 46. Prathik Kumaar B. et al., Review of mobilenet variants for effective land use land cover classification : a study with light weight models	ID 69. Lavanya M., Assessment of ensemble learning techniques for predicting delamination factor (fd) in abrasive water jet machined sic-reinforced jute epoxy composites
13h30 - 13h45	ID 17. Zelikha Belhamri et al., A Comparative study of automatic number plate recognition (ANPR) methods	ID 20. Bachir NAAS et al., Design and implementation of a GSM-Based fire alarm system using ATmega328P	ID 70. Lavanya M. Application of machine learning for predicting surface roughness (ra) in abrasive water jet machined ti-6al-4v mmcs
13h45 - 14h00	ID 24. Nasreddine Karour et al., Recent Wireless sensor networks localization techniques: A Review	ID 21. Hamza BENYEZZA et al., IoT-Driven platform for energy meter enhancement and consumption monitoring	ID 71. Lavanya M., Application of machine learning for predicting kerf angle (ka) in abrasive water jet machining in glass fibre epoxy composites
14h00 – 14h15	ID 27. Akram ADNANE et al., Combined robust attitude control and positive position feedback compensation for a flexible satellite	ID 22. Mohammed Ferradj Noureddine Benouzza, Line current analysis as a technique to detect bearing faults in permanent magnet synchronous motors	ID 72. Lavanya M., Machine learning-based prediction of tensile strength in pineapple fiber reinforced polymer composites incorporating cuo filler using random forest, decision tree, and xgboost algorithms
14h15-14h30	ID 60. Younes Belhadjer et al., Comparative evaluation of MPC, FOPID, and TID controllers for autonomous vehicle steering	ID 23. Radia Tabet Derraz et al., Design of an ultra-wideband circularly polarized microstrip patch antenna for sub-6 GHz 5G Mobile applications	ID 73. Lavanya M., Machine learning-based prediction of impact strength in araca fibre epoxy/sic polymer composites using decision tree, random forest and xgboost

Program

IEEE 2025 : The 5th International Conference on Applied Automation and Industrial Diagnostics – **ICAAID 2025 -**
Ghardaïa, Algeria | 18-20 November 2025

18/ 11 / 2025 : Virtual Sessions

	Session 4	Session 5	Session 6
Chairs	**Dr B. Kourich, Prof. Benalia Mhamedi**	**Dr C.A. Mosbah, Dr Dahmane Djandaoui**	**Dr Fares Fenniche, Dr Fatma Bouchelga**
14h30 - 14h45	ID 28. Fatima Souad Bezzaoucha et al., Real-time damage detection and classification in wind turbine gearboxes using Ferderated learning	ID 45. Kamel Touati, Lamia Cheklat, An integrated AI framework for unsupervised wildfire risk prediction and automated detection	ID 55. Medoukali Hemza et al., Machine learning diagnosis-based of hvdc faults
14h45 - 15h00	ID 33. Sivakumar Rajendran, Automated detection of lung disease using deep learning techniques: a comparative study	ID 47. Wiame Guenaya et al., Design and optimization of an energy storage system for an electric wheelchair with integrated solar assistance	ID 57. Amar Gouri et al., Enhancing reliability in industrial systems through the universal motor controller umc100.3: Failure analysis, prognostics, and risk-based maintenance
15h00 - 15h15	ID 34. Indrawata Wardhana et al., Robust peak detection of shifting fault characteristic frequencies for bearing	ID 50. Ehsan Esmaeeli et al., Optimizing maintenance part allocation using association rules and mixed-integer linear programming	ID 62. Ali Teta et al., Deep learning framework for short-circuit fault detection in photovoltaic systems using infrared thermography
15h15 - 15h30	ID 35. Hiba Abir Chemakh et al., Enhancing horizontal partitioning in DBMS through machine learning-guided metaheuristics	ID 118. Sabah Lecheheb et al., Automated deep learning and incremental retraining-driven MAPE-K analyzer architecture for intelligent self-adaptation	ID 116. Oumaima Gharsa et al., Autonomous landing of a quadrotor on a moving target using a vision-based approach
15h30 – 15h45	ID 39. Nadia Hoggas et al., Advancing milk quality prediction: Dynamic stacking ensemble with quality-aware adaptive sampling	ID 94. Moulay Kheireddine et al., Fault diagnosis of submodule capacitors in modular multilevel converters using intelligent method	ID 123. Wassan Adnan Hashim, et al., Multi-agent energy optimization in connected HEV convoys via MPC and reinforcement learning
15h45 – 16h00	ID 44. Taha Bachir Ammour et al., Bio-inspired swarm intelligence approaches to wireless sensor network optimization: innovations and applications	ID 114. Hafidha Boudouaia et al., Predictive maintenance of rotating machine in petrochemical plants using a hybrid KNN and RPN methodology	ID 131. Abdelhak Djellad et al., Sensor fault diagnosis and switched fault-tolerant control for gas turbines using wavelet features and random forest classifier
16h00- 16h15	ID 119. Sabah Lecheheb et al., Automated deep learning and incremental retraining-driven MAPE-K analyzer architecture for intelligent self-adaptation	ID 82. Amina Azizi, Benabda Amina, Experimental and Numerical Study of the Impact of Shading on a Photovoltaic System with Conventional and Advanced MPPT Controls	ID 86. Amira Lakhdara et al., MPC-based speed tracking for PMSM electric vehicles

Program

IEEE 2025 : The 5th International Conference on Applied Automation and Industrial Diagnostics – **ICAAID 2025 -**
Ghardaïa, Algeria | 18-20 November 2025

18/ 11 / 2025 : Virtual Sessions

	Session 7	Session 8	Session 9
Chairs	**Dr Hamed Boukhari, Dr Hemza Medoukali**	**Prof. Kaddouri A. Miloud, Dr Khaled Ferkous**	**Pror. L. Mokrani, Dr Mohammed Aouf**
16h15 - 16h30	ID 132. Tahar Boukra, Smail Bazi, a hybrid approach for RUL prediction of li-ion batteries using GRU-based additive attention	ID 88. PrathikKumaar B., Deepak A., Image based air quality level assessment using mobilenet and ResNet152V2	ID 74. Lavanya M., Prediction of impact strength in coir fibre reinforced epoxy composites using decision tree, random forest, and xgboost model
16h30 - 16h45	ID 129. Belkacem Houara et al., Advanced control of a hybrid PV–wind energy conversion system with STSMC-based dc-link regulation and dpc grid integration	ID 89. PrathikKumaar B., Deepak A. Optimized deep neural network architecture for high-performance weed detection with lightweight MobileNetV3 and enhanced ConvNeXt small	ID 75. Shanmuga Priya S. et al., A hybrid ids (h-ids) model for iomt security: combining machine learning and deep learning techniques
16h45 - 17h00	ID 130. Mehdi Fazilat, Nadjet Zioui, A brief review on quantum-based control strategies for robotic systems	ID 100. Abdelkader Garmat, Kamel Guesmi, Sliding mode control of flying-capacitor voltage in serial multi-cell dc-dc converters	ID 83. Xopo-Rodriguez B. L.. et al., Disturbance rejection control system for stabilizing a driverless two-wheeled vehicle
17h00 - 17h15	ID 156. Abdesattar Mazouzi, et al., Improved efficiency of the fuel cell vehicle energy management system: a multi-phase optimization approach	ID 143. Mouhcen El Hadi Dahmoun, Khaoula Salima Reguieg, Smart energy management of pv–hybrid storage systems for sustainable grid integration	ID 92. Neal Stephen Reon C. Rajinikanth V., Deep-learning scheme to accurately classify the retinal OCT into normal/ AMD with MobileNetV1 than EfficientNetB1
17h15 – 17h30	ID 140. Gamboa-Escobar AJ., et al., Sustainable production and automation: A case study on anaerobic digestion of dairy industry wastewater	ID 141. Neal Stephen Reon C. Rajinikanth V., Improving accuracy with VGG16 based normal/drusen retinal oct images compared with ResNet152 results	ID 85. Bahena-Bustamante E. et al., Takagi-Sugeno unknown input observer for secure communication of nonlinear chaotic systems
17h30 – 17h45	ID 135. Mokhtar Khenfer, improving CSTR performance using a super-twisting sliding mode controller	ID 136. El Arkam Mechhoud et al., Automated risk assessment approach using d-higraph integrated into DCS apllied on fired heater	ID 97. Amina Azizi, Benabda Amina, Enhancement of the electrical energy quality of a grid connected photovoltaic panel
17h45- 18h30	ID 149. Nacera Bekhadda et al., Fuel consumption prediction of non-coplanar orbital transfer using machine learning techniques	ID 165. khaled sahraoui et al., System reconfiguration under open-circuit faults based on five/four-legs converter using zero-sequence voltage	ID 99. Junia Maisa De Oliveira et al., Applying correlation equations to distance matrices to introduce noise and improve model-AI performance

Program

IEEE 2025 : The 5th International Conference on Applied Automation and Industrial Diagnostics – ICAAID 2025 -
Ghardaïa, Algeria | 18-20 November 2025

19/ 11 / 2025

8 h 30 – 9 h 30	**Plenary Session 3** **Power electronics and hybrid transformers in distributed energy system - opportunities and challenges** **Professor Mariusz Malinowski** Warsaw Technical University, Warsaw, Poland **Chairs : Prof. Lakhder Moukrani and Professor Mostefa Mohamed-Seghir**
09 h 30 – 10 h 30	**Presentation of IEEE Algeria Section** **Professor Abdellah Kouzou** University of Djelfa, Algeria **Chairs : Prof Soumia KOUADRI MOUSTEFAI**
10 h 30 – 11 h 00	**Coffee break**

Program

IEEE 2025 : The 5th International Conference on Applied Automation and Industrial Diagnostics – **ICAAID 2025 -**

19/ 11 / 2022 : Virtual Sessions Ghardaïa, Algeria | 18-20 November 2025

	Session 1	Session 2	Session 3
Chairs	**Prof. N. Henini, Dr Oussama Moussa**	**Dr Rafik Euldji, Dr Redha Kara**	**Dr Smain Bentouati, Dr Tahar Djellouli**
11h10 - 11h15	ID 102. Joaquin Hernandez Santiago et al., Coupled dynamic–kinematic modeling of an autonomous ground vehicle with aerodynamic forces: drag, side force, and yaw moment	ID 125. Salima Khaoula Reguieg, Mouhcen El-hadi Dahmoun, Performance monitoring and fault diagnosis of piezoelectric accelerometers using optimized sensitivity modeling	ID 139. Bilal Benarabi et al., Real-time communication between different types of plcs and matlab with fuzzy controller integration via OPC: a desalination plant as a case study
11h15 - 11h30	ID 104. Ameur Fethi Aimer et al., Condition monitoring of simultaneous faults in variable speed induction motor operation	ID 124. Sabah Lecheheb, et al., automated deep learning and incremental retraining-driven mape-k analyzer architecture for intelligent self-adaptation	ID 150. Assala Bouguerra et al., Addressing shading challenges: an improved carpet weaver optimization mppt method for effective tracking in shaded circumstances
11h30 - 11h45	ID 167. Derradji Bakria et al., A Hybrid Deep-Machine Learning Approach to Diagnose Partial Shading and Short-Circuit Faults in Solar Photovoltaic Systems using Infrared Thermography Images	ID 122. Ramos Hernandez E. et al., Observer-based estimation for an essential oil extraction system	ID 121. Afouf Oussama et al., Intelligent weather forecasting system based on internet of things for smart cities
11h45 - 12h00	ID 166. Hamza Adaika et al., Enhancing maintenance agility in water desalination plants via explainable MCSA: a case study on workflow integration and diagnostic efficiency	ID 128. Fouad Zebiri et al., Dspace real-time implementation of mppt-based direct method	ID 146. Messaoud Babaghayou et al., UAV LINK: A UAV-assisted communication framework for smart farming in isolated environments using satellite-based edge computing
12h00 - 12h15	ID 163. Ihssane Houhou et al., Comparative analysis of deep learning models for background subtraction on LASIESTA	ID 161. Selma Amrani et al., RT-driftselect: A real-time dynamic feature selection framework for concept drift adaptation in SDN-IoT environments	ID 127. Riad Bendib, et al., Design of an advanced optimal sliding mode controller for a laboratory process using methaheuristic approaches
12h15 - 12h30	ID 162. Rahma Berchi et al., MV-EA-IDS: an optimized dual view, energy-aware ids for battery drain attacks in IoT	ID 145. Hichem Merabet et al., Performance analysis of a three-level z-source converter controlled by a predictive strategy	ID 160. Sarah Benziane, Adaptive anisotropic diffusion with dynamic z-score thresholding for efficient low-contrast defect detection in textured metal surfaces

Program

IEEE 2025 : The 5th International Conference on Applied Automation and Industrial Diagnostics – **ICAAID 2025 -**

Ghardaïa, Algeria | 18-20 November 2025

19/ 11 / 2022 : Virtual Sessions

	Session 1	Session 2	Session 3
Chairs	**Prof. N. Henini, Dr Oussama Moussa**	**Pror. Tamersit K., Pror. Yahia Bakkeli**	**Dr Smain Bentouati, Dr Tahar Djellouli**
12h15 - 12h30	ID 107. Mohamed Mami et al., Physical modeling and simulation of a thermoelectric device with PID-based control	ID 111. Mounia Ticherfatine, Constrained model predictive control with disturbance predictions for a fast ferry's vertical motions stabilization	ID 117. Soumia Khedimi et al., Language models and bidirectional recurrent neural networks for arabic named entity recognition
12h30 - 12h45	ID 133. Hamza Zerrouki, Dynamic safety evaluation of gas treatment processes	ID 134. Hamza Zerrouki, Fault tree-based bayesian network for probabilistic safety assessment	ID 142. Amar Souissi et al., Optimization of maintenance scheduling for wind farms using genetic algorithm
12h45 - 13h00	ID 153. Lalia Miloudi et al., Design of sliding mode control applied to inverted cart-pendulum for good stability performances	ID 154. Nahed Ghanay, et al., State-of-charge estimation of lithium-ion batteries using a fuzzy c-regression model (FCRM) approach	

Program

IEEE 2025 : The 5th International Conference on Applied Automation and Industrial Diagnostics – **ICAAID 2025 -**
Ghardaïa, Algeria | 18-20 November 2025

12 h 30 – 13 h 00	**Closing Ceremony**
13 h 00	**Lunch**