JCARM
Journal of Contemporary Academic Research and Methodologies

An Online Peer Reviewed / Refereed Journal
Volume 1 | Issue 4 | May 2026
Website: www.journal.jcarm.in

Research

Control in Robotics and Autonomous Systems in Nigeria: Current Landscape, Challenges, and Strategic Pathways

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Abstract: This article looks at control systems in robotics and autonomous systems (RAS) within Nigeria. Despite worldwide progress in feedback control, optimal estimation, and learning-based autonomy, Nigeria's RAS sector is still developing. It's marked by scattered research, minimal industrial use, and inadequate infrastructure. We review various control methods, including PID, LQR, MPC, and adaptive control, and evaluate their relevance to Nigerian applications, such as agricultural drones, self-driving cars for road safety, pipeline monitoring, and medical robotics. By combining a literature review with expert surveys (n=30), we uncover key obstacles: unreliable power supply, no local sensor production, weak connections between universities and industries, and a lack of national RAS standards. While Nigerian researchers show solid theoretical understanding (over 70% familiarity with PID and MPC), the practical application is under 10% due to hardware limitations. A comparative table of control methods against application readiness is included. We conclude that a phased plan, starting with inexpensive embedded control for agriculture and progressing to durable off-grid autonomy, is crucial. Recommendations include a national curriculum for control systems, public-private testbeds, and regulatory frameworks for certifying autonomous systems.

Keywords: Robotics control, autonomous systems, Nigeria, adaptive control, low-cost automation

1. Introduction

The Fourth Industrial Revolution has positioned robotics and autonomous systems (RAS) as crucial to technological progress. Control theory is the mathematical foundation of RAS, allowing systems to retain desired behaviors in the face of disturbances and uncertainties. Countries like China, Germany, and South Korea have integrated RAS into

https://doi.org/10.5281/zenodo.20605000

manufacturing, logistics, agriculture, and defense, achieving productivity gains of 20-30% (B. Siciliano et al., 2019). In Africa, South Africa and Kenya lead in RAS adoption with drone delivery systems and autonomous mining equipment (ADB, 2021). Nigeria, the largest economy in Africa, faces a contradiction: a vibrant tech ecosystem (like FinTech and agri-tech startups) but minimal use of robotics control in critical sectors. Agriculture employs more than 35% of the workforce, yet post-harvest losses hit 40% due to poor monitoring and control (NBS, 2023). Over 10,000 lives are lost each year in road traffic accidents, a situation that collision-avoidance control systems could help alleviate (FRSC, 2022). Pipeline vandalism in the Niger Delta results in billions of dollars in losses, yet autonomous inspection robots are lacking (NNPC, 2023).

Control in RAS includes classical PID (Proportional-Integral-Derivative) for simple regulation, Linear Quadratic Regulator (LQR) for optimal trade-offs, Model Predictive Control (MPC) for managing constraints, and adaptive/robust control for uncertain environments (K.J. Astrom and R.M. Murray, 2021). Research literature in Nigeria is limited. A 2022 survey found that fewer than 15% of Nigerian engineering departments offer a specialized robotics control course (NUC, 2022). University projects often simulate control algorithms (like MATLAB/Simulink) but rarely implement them on physical hardware due to import issues and unstable power (O. Adewale, 2023). Furthermore, local autonomous systems face unique challenges, such as high dust affecting sensors, unreliable GPS in urban areas (like Lagos and Kano), and extreme temperatures damaging actuators (T. O. Olaleye, 2022). Overcoming these challenges requires not just control theory but also low-cost, durable implementation strategies.

This article poses three questions: (i) Which control methods are most relevant for Nigerian RAS applications? (ii) What are the measurable gaps between theoretical knowledge and practical application? (iii) What steps can speed up control-enabled autonomy in Nigeria? The next sections review existing research (Section 2), outline the methodology (Section 3), present results (Section 4), and share recommendations (Section 5). The conclusion summarizes findings and future directions (A. G. O. Mutiu, 2023).

2. Literature Review

Current research on control in RAS for developing countries, especially Nigeria, is limited, though it is increasing. Globally, classical control remains fundamental. PID controllers are popular for low-cost robotic arms and mobile robots because of their simplicity and lack of model requirements (G. F. Franklin et al., 2019). However, PID struggles with constraints (like actuator saturation), leading to the use of MPC in autonomous vehicles, where prediction horizons help avoid collisions (J. B. Rawlings et al., 2020). For Nigerian applications, researchers have suggested using adaptive control for agricultural rovers on uneven, rain-damaged terrain, showing a 25% improvement in trajectory tracking compared to fixed-gain PID (C. O. Ibeh and L. A. Akinyemi, 2022).

In Nigeria, (M. N. Eze and P. O. Okonkwo (2021) created a simulation for an autonomous unmanned ground vehicle (UGV) for pipeline monitoring using a combination of PID and LQR. Their study pointed out that while LQR provides optimal results, the need for full-state feedback (which requires multiple sensors) poses a cost barrier (M. N. Eze and P. O. Okonkwo, 2021). (T. Akinwale et al., 2023) assessed fuzzy logic control (FLC) and PID for a drone used in crop spraying. FLC performed better in windy conditions (common during the Nigerian harmattan) but needed more computational resources, which is a challenge for low-end microcontrollers (T. Akinwale et al., 2023).

The literature also notes a persistent "simulation-to-reality" gap. (K. Oyedeji, 2022) surveyed 120 Nigerian engineering final-year projects and found that over 80% of RAS control projects remained in simulation; only 5% created a physical prototype, and none were field-tested. Factors included difficulty sourcing motors, sensors, and microcontrollers due to foreign exchange constraints, and a lack of machine shops for custom mechanical parts (K. Oyedeji, 2022). Additionally, there are no national standards or certification frameworks for autonomous systems, which hinders industry confidence. The African Robotics Network (AFRON) reports that Nigeria ranks 24th out of 54 African nations in robotics deployment density (robots per 10,000 workers) (AFRON, 2023). To summarize, while there is theoretical knowledge in control, translating it into functioning systems is blocked by economic and infrastructure issues. This study aims to measure these gaps and suggest a control roadmap that suits the local context.

3. Methodology

A mixed-methods approach was used, combining a systematic literature review with a survey of Nigerian RAS professionals. The study took place from January to June 2024.

3.1 Literature review strategy

We searched Scopus, IEEE Xplore, Google Scholar, and African Journals Online using the keywords: "robotics control Nigeria," "autonomous systems Nigeria," "adaptive control tropical," and "low-cost autonomy." The criteria included: (i) published between 2018 and 2024, (ii) at least one Nigerian author or case study, and (iii) focus on control algorithms. We filtered 42 papers, from which 6 are cited in the literature review (Section 2). Additional global foundational texts (like Franklin and Rawlings) provided theoretical support.

3.2 Survey design and sample

We created a 20-question online questionnaire (Google Forms) targeting: (i) academic researchers in Nigerian universities with robotics labs, (ii) engineers in agri-tech, oil & gas, and logistics startups, and (iii) lecturers teaching control engineering. The survey collected data on demographics, familiarity with 12 control methods (using a Likert scale of 1–5), deployment experience (simulation, prototype, field), barriers (multiple choice), and preferred applications. A convenience sample of 30 respondents was gathered (20 academics, 10 industry). Respondents came from six Nigerian states (Lagos, Oyo, FCT, Rivers, Kano, Enugu).

3.3 Data analysis

We analyzed quantitative data using descriptive statistics (mean, percentage). Familiarity scores were averaged for each control method. Deployment stages were categorized as: simulation only (no hardware), prototype (physical but lab-tested), and field-tested (outdoor in the intended environment). Barriers were ranked by frequency. All responses remained anonymous.

3.4 Ethical consideration

Participation was voluntary, and informed consent was obtained. No personal identifiers were gathered.

Table 1: Survey respondent categories and distribution

Category	**Number of respondents**	**Percentage**	**Source of data**
Academic (research)	15	50%	Primary survey (2024)
Academic (teaching only)	5	16.7%	Primary survey (2024)
Industry (agri-tech)	5	16.7%	Primary survey (2024)
Industry (oil & gas)	3	10%	Primary survey (2024)
Industry (logistics)	2	6.6%	Primary survey (2024)
Total	30	100%	
Source: Authors’ field survey, 2024.			

4. Results and Discussion of Findings

4.1 Familiarity with control methods

Respondents rated their familiarity with 12 control methods (1 = not familiar, 5 = highly familiar). Table 2 shows the average scores.

Table 2: Familiarity with control methods among Nigerian RAS practitioners

Control method	Mean familiarity (1–5)	Standard deviation	Source of data
PID control	4.7	0.6	Primary survey (2024)
LQR (Linear Quadratic Regulator)	3.8	1.1	Primary survey (2024)
Model Predictive Control (MPC)	2.9	1.3	Primary survey (2024)
Adaptive control	2.5	1.4	Primary survey (2024)
Robust control (H‑infinity)	2.1	1.5	Primary survey (2024)
Sliding mode control	2.3	1.4	Primary survey (2024)
Fuzzy logic control	3.2	1.2	Primary survey (2024)
Neural network control	2.7	1.3	Primary survey (2024)
Reinforcement learning control	2.0	1.4	Primary survey (2024)
Gain scheduling	2.8	1.2	Primary survey (2024)
Backstepping	1.9	1.3	Primary survey (2024)
Lyapunov‑based control	2.2	1.4	Primary survey (2024)
Source: Authors' survey data, 2024.			

Discussion: The high familiarity with PID (4.7) indicates its prominence in education. MPC, while important for autonomous vehicles, scores only 2.9, showing a gap in teaching advanced optimal control. Adaptive and robust methods, scoring below 2.5, are concerning for Nigerian situations with high uncertainty (like dust and GPS loss). The low score for RL control (2.0) reflects limited computing resources.

4.2 Deployment stage of robotics control projects

Table 3: Highest deployment stage achieved by respondents

Deployment stage	Number of respondents	Percentage	Source of data
Simulation only	19	63.3%	Primary survey (2024)
Physical prototype (lab)	8	26.7%	Primary survey (2024)
Field-tested (outdoor)	3	10.0%	Primary survey (2024)
Commercial product	0	0%	Primary survey (2024)
Source: Authors' survey data, 2024.			

Discussion: Over 63% of respondents never move past simulation, and only 10% reach field testing. No one reported having a commercial RAS product. This sharply contrasts with global figures, where 40-50% of university RAS projects reach the prototype stage (K. Oyedeji, 2022). The gap between simulation and reality in Nigeria mainly stems from a lack of available hardware (see barriers, Section 4.3).

4.3 Barriers to practical deployment of control systems

Respondents identified all applicable barriers. Table 4 ranks them.

Table 4: Perceived barriers to practical RAS control deployment

Barrier	Frequency (n=30)	% of respondents	Source of data
High cost of sensors/actuators/microcontrollers	28	93.3%	Primary survey (2024)
Erratic power supply (lab/field)	26	86.7%	Primary survey (2024)
Lack of local manufacturing for robotic parts	24	80.0%	Primary survey (2024)
Poor internet for cloud-based control (e.g., ROS)	21	70.0%	Primary survey (2024)
Absence of industry-academia collaboration	20	66.7%	Primary survey (2024)

Limited training in hardware interfacing	18	60.0%	Primary survey (2024)
No national standards for autonomous systems	17	56.7%	Primary survey (2024)
Foreign exchange unavailability for imports	15	50.0%	Primary survey (2024)
Source: Authors' survey data, 2024			

Discussion: Cost and power rank as the top two barriers, aligning with national infrastructure issues. Notably, "no national standards" was cited by 56.7% of respondents, showing that even if technical solutions were available, regulatory uncertainty hinders industrial adoption.

4.4 Application areas with the highest perceived impact

Table 5: Preferred application areas for RAS control in Nigeria

Application	**Mean priority (1 = low, 5 = high)**	**Source of data**
Agricultural drones/sprayers	4.8	Primary survey (2024)
Pipeline monitoring UGVs	4.6	Primary survey (2024)
Autonomous road vehicles (collision avoidance)	4.4	Primary survey (2024)
Medical/surgical robotics	3.7	Primary survey (2024)
Warehouse/logistics robots	4.2	Primary survey (2024)
Search and rescue (after floods)	4.0	Primary survey (2024)
Source: Authors' survey data, 2024.		

Discussion: Agriculture ranks highest (4.8), reflecting Nigeria's agricultural economy and the government's support for mechanization. Pipeline monitoring (4.6) relates to concerns about oil theft. Surprisingly, medical robotics scored lower (3.7), likely due to stricter regulations and sterility requirements.

4.5 Key findings synthesis

Three main findings stand out:

1. Knowledge-practice mismatch: There is a high theoretical understanding of basic control (PID), but field deployment is minimal.
2. Infrastructure as a major barrier: Even well-designed controllers fail without powered sensors or accessible actuators.
3. Context-appropriate control pathways: While MPC and adaptive control are desirable, they require significant computation; currently, low-cost embedded PID with feedforward is more feasible for Nigeria.

5. Conclusion

This article analyzed control in robotics and autonomous systems in Nigeria. We found that while Nigerian academics and industry professionals understand classical control methods (especially PID), they underuse advanced techniques like MPC, adaptive, and learning-based control due to training gaps. More importantly, less than 10% of control-related RAS projects move to field testing, with hardware costs, erratic power supply, and lack of local manufacturing identified as the top barriers. Agricultural monitoring, pipeline inspection, and collision avoidance are the highest priority applications. The lack of national standards and collaboration between industry and universities hampers commercialization. However, there is a strong grasp of fundamental control concepts that can serve as a basis for targeted interventions, such as low-cost embedded control kits, solar-powered testbeds, and curriculum updates. Future efforts should focus on creating a Nigerian-specific control benchmark (e.g., dust-tolerant PID with anti-windup) and pilot projects in rural agricultural settings.

6. Recommendations

Based on the findings, we suggest the following practical recommendations:

R1 – National Robotics Control Curriculum

The National Universities Commission (NUC) should create a mandatory 2-credit course on “Embedded Control for RAS.” This should focus on low-cost microcontrollers (ESP32, STM32), sensor calibration for tropical climates, and PID implementation with anti-windup. Hands-on labs with locally assembled robot kits should replace purely simulation projects.

R2 – Public-Private Testbeds

Establish three regional RAS testbeds: North-central for agriculture, South-south for pipeline monitoring, and South-west for logistics, outfitted with solar power, GPS stations, and shared affordable actuators and sensors. Funding should come from TETFund (Tertiary Education Trust Fund) and oil companies through CSR.

R3 – Regulatory Framework for Autonomous Systems

The National Information Technology Development Agency (NITDA) and the Standards Organisation of Nigeria (SON) should develop a "Code of Practice for Ground and Aerial Autonomous Systems." This should address safety, data privacy, and certification of control software, starting with low-speed agricultural robots (<10 km/h) before addressing road autonomy.

R4 – Industry-University Fellowship Programme

Create a 6-month fellowship for 30 Nigerian engineers per year to tackle real RAS control issues (e.g., developing adaptive control for drone spraying). This should be sponsored by the African Development Bank's Coding for Employment program, with a deliverable of a field-tested prototype.

R5 – Low-Cost National Robotics Platform

Design a "NaijaBot" open-source hardware platform costing around ₦50,000 (approximately $30). This should use locally 3D-printed parts, DC motors with encoders, and a PID library. Mass production should be organized through the National Agency for Science and Engineering Infrastructure (NASENI), with each engineering faculty receiving 20 kits.

R6 – Power-Resilient Control Design

Research grants should prioritize developing control algorithms that can cope with intermittent power (e.g., energy-aware MPC and graceful degradation). The Nigerian Communications Commission (NCC) can fund studies on off-grid autonomy.

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