AGRICULTURAL IoT SYSTEM WITH EDGE INTELLIGENCE

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Agricultural IoT System with Edge Intelligence

Background :

➢ Current Limitations in Agricultural IoT:

✓ Basic Monitoring Only: Existing systems provide data collection without intelligent decision-making capabilities
✓ Lack of Predictive Analytics: No real-time autonomous control or predictive insights for precision agriculture
✓ Language Barriers: Limited multilingual support restricts knowledge sharing across ASEAN region
✓ Security Vulnerabilities: Inadequate protection against evolving cyber threats in distributed IoT networks

Critical Gap: ASEAN agriculture needs intelligent, autonomous systems that integrate expert knowledge with real-time IoT analytics while ensuring robust cybersecurity and multilingual accessibility.

Agricultural IoT System with Edge Intelligence

Research Objectives

Objective 1: Multimodal AI Integration

Develop and deploy a Multimodal Mixture-of-Experts (MoE) model integrated with multilingual RAG-LLM capabilities, combining expert knowledge with IoT data analytics for enhanced decision support across Vietnamese, Thai, Malay, and English.

Objective 2: Autonomous Edge Control

Build autonomous control systems powered by edge intelligence, enabling real-time decision-making, optimising operations over semantic communication.

Objective 3: Intelligent Cybersecurity

Design an intelligent cybersecurity framework adaptable to 5G/6G networks, ensuring data safety and protection against complex threats using AI-driven anomaly detection.

Proposed Method: WP1 - Multimodal MoE with RAG-LLM

Architecture & Approach

- ✓ Multimodal Mixture-of-Experts (MoE): Specialized expert modules for different agricultural domains
- ✓ RAG-LLM Integration: Retrieval-Augmented Generation for accessing expert knowledge bases
- ✓ Multilingual Support: Vietnamese, Thai, Malay, and English language processing

Key Tasks

- ✓ Dataset harmonisation across ASEAN countries
- ✓ MoE model optimisation for context-aware analytics
- ✓ Cross-linguistic knowledge transfer
- ✓ System validation with real-world scenarios

Expected Outcomes

- ✓ Robust AI-driven decision support system
- ✓ Actionable recommendations for precision agriculture
- ✓ Enhanced reasoning across linguistic boundaries
- ✓ Superior inference accuracy over general LLMs

Proposed Method: WP2 - Autonomous Edge Control

Edge Intelligence Architecture

- ✓ TinyML Models: Lightweight AI/ML algorithms executing on resource-constrained edge devices
- ✓ Local Processing: Real-time data processing and autonomous actuation at the edge
- ✓ Digital Twin Integration (small case): Predictive simulation and resource optimization

Implementation Strategy

- ✓ Deploy edge computing nodes for local processing
- ✓ Embed AI/ML for autonomous irrigation & fertilization
- ✓ Enable real-time pest management
- ✓ Conduct field trials in Vietnam & Malaysia & Thailand

Key Benefits

- ✓ Minimal latency in decision-making
- ✓ Reliable operation in limited connectivity
- ✓ Optimized resource consumption
- ✓ Reduced dependency on cloud infrastructure

Partly autonomous control systems that adapt to field conditions in real-time, even with poor network connectivity.

Proposed Method: WP3 - Intelligent Cybersecurity

Security Framework Components

- ✓ ML-Based Anomaly Detection: AI-powered threat identification and early detection
- ✓ Blockchain-Enabled Integrity: Data auditability and tamper-proof storage
- ✓ 5G/6G Compatibility: Secure distributed IoT deployments on next-gen networks

Technical Approach

- ✓ Lightweight, scalable security architecture
- ✓ Automated threat detection & response
- ✓ XAI for enhanced reliability
- ✓ Privacy-aware data protection

Cost-Effective Solution

- ✓ Eliminates licensing costs
- ✓ Accessible to SMEs without security staff
- ✓ User-friendly web & mobile dashboards
- ✓ Continuous learning from network patterns

Validation: Penetration testing, simulation, and real-world deployment across Vietnam, Malaysia, and Thailand.

Implementation Plan & Timeline

24-Month Project Duration

Phase 1: System design, dataset harmonization, initial development (Months 1-6)

Phase 2: Model training, edge deployment, security framework development (Months 7-12)

Phase 3: System integration, field trials, validation (Months 13-18)

Phase 4: Optimization, comprehensive demonstration, dissemination (Months 19-24)

International Consortium

PTIT (Vietnam)
Lead institution, system integration

VNU-UET (Vietnam)
Agricultural expertise, validation

UTM (Malaysia)
Regional deployment

Khon Kaen (Thailand)
Regional deployment

NICT/ Ritsumeikan (Japan)
AI/ Security enhancement

Mimosatek (Vietnam)
Technology transfer

Field Testing & Validation Strategy

Testing Locations

- ✓ Vietnam: Experimental farms via VNU-UET network and PTIT facilities
- ✓ Malaysia: UTM agricultural collaborators for precision agriculture
- ✓ Thailand: Khon Kaen partners for agriculture validation

Validation Metrics

- ✓ Decision accuracy and response time
- ✓ Resource optimization (water, fertilizer, energy)
- ✓ Crop yield improvement
- ✓ System reliability and uptime
- ✓ Security threat detection rate

Experimental Design

- ✓ Controlled environment testing
- ✓ Commercial farm deployment
- ✓ Multi-crop validation (tomato, vegetables, fruits)
- ✓ Diverse climate conditions
- ✓ Penetration testing for security

Technology Transfer

- ✓ Farmer training programs
- ✓ Agricultural cooperative partnerships
- ✓ Government extension services
- ✓ Local technical support networks

Scientific & Technological Impact

1. Intellectual Merit - Novel MoE Architecture

First multimodal Mixture-of-Experts model combining farmer/expert knowledge with heterogeneous IoT data, enabling context-aware reasoning superior to general LLMs in agricultural domains.

2. Edge Intelligence Advancement

TinyML models for resource-constrained devices enabling responsive agricultural systems with poor connectivity, advancing the frontier of edge computing research.

3. Next-Generation Cybersecurity

Security framework for AI/ML attack prevention, early detection, and 5G/6G integration with XAI-enhanced reliability, addressing emerging threats in distributed IoT systems.

4. Multilingual Knowledge Transfer

Cross-linguistic agricultural advisory system breaking language barriers across ASEAN, enabling inclusive technology adoption and knowledge sharing.

Publications: 4 high-impact journal papers + 4 international conference papers

Societal Impact & Sustainability

Economic Benefits

- ✓ Resource Optimization: Reduced water, fertilizer, and energy consumption
- ✓ Yield Improvement: Enhanced crop productivity through precision agriculture
- ✓ Cost Reduction: Lower operational costs for farmers
- ✓ Market Access: Technology transfer to SMEs and cooperatives

Environmental Impact

- ✓ Carbon Neutrality: Optimized resource use supporting climate goals
- ✓ Sustainable Practices: Reduced chemical usage and waste
- ✓ Water Conservation: Intelligent irrigation management
- ✓ Biodiversity Protection: Precision pest control

Social Inclusion & Digital Divide

Multilingual advisory solutions enable farmers to access optimal agronomic techniques tied to traditional practices, bridging the digital gap across diverse ASEAN communities.

Regional Collaboration

Multi-institutional alliance (Vietnam-Malaysia-Thailand-Japan) establishes long-term capacity building, technology transfer, and policy alignment for replicable, scalable solutions.

Project Outputs & Outcomes

Scientific Outputs

- ✓ Novel Technologies: Multimodal MoE-RAG-LLM architecture, TinyML for edge devices, AI-driven cybersecurity framework
- ✓ Open-Source Platform: Free network monitoring tool for agricultural IoT security
- ✓ Digital Twin Platform: Predictive simulation system for resource optimization
- ✓ Research Publications: 8 peer-reviewed papers advancing smart agriculture knowledge

Societal Outcomes

- ✓ Technology Transfer: Deployment through agricultural cooperatives and government extension services
- ✓ Capacity Building: Comprehensive farmer training programs and local technical support networks
- ✓ Public Datasets: Harmonized agricultural data for ASEAN research community
- ✓ Policy Recommendations: Guidelines for smart agriculture adoption and cybersecurity standards

Collaborative Outcomes

- ✓ International Workshop: 'Edge Intelligence and Multilingual AI for Smart Agriculture' in Vietnam
- ✓ Multi-Country Demonstrations: Field showcases across Vietnam, Malaysia, and Thailand
- ✓ New Partnerships: Expanded ASEAN research network and industry collaborations

Project Outputs & Outcomes

PROJECT EXTENTIONS and EVOLUTION

PREVIOUS PROJECT (2022-2024)

SECURITY ISSUES
- IDS-based ML
- SDN/NFV security
- IoT device protection
- Basic IoT threat detection

DISEASE DETECTION
- Image processing
- Lightweight ML models
- Basic classification
- Single language decission support

SYSTEM DEVELOPMENT
- Greenhouse deployment
- Disease IoT data collection
- Basic monitoring
- Manual control

APPLICATIONS
- Voice irrigation module
- Disease dictionary (VLLM)
- Basic user interface (intergrated)

KEY LIMITATIONS
- ✗ No autonomous decision-making
- ✗ Single language (Vietnamese only)
- ✗ No semantic communication
- ✗ Basic security framework
- ✗ High bandwidth consumption

KEY TRANSFORMATION ISSUES
- ✓ AI on Edge Upgrade (MoE+RAG-LLM)
- ✓ Communication Enhanced (Semantics Communication)
- ✓ Security Enhancement (XAI, Related to 5G/6G security)
- ✓ Geographic Expansion (VN, Th, ML, En actuators control)

PROPOSED ASEAN IVO PROJECT (2025-2027)

WP1: MULTIMODAL MoE + RAG-LLM
- ✓ Expert knowledge integration (agricultural domain)
- ✓ Multilingual support (Vietnamese, Thai, Malay, English)
- ✓ Context-aware reasoning and decision-making
- ✓ Superior performance to general-purpose LLMs
- ✓ RAG for real-time knowledge updates

WP2: EDGE INTELLIGENCE + SEMANTIC COMM
- ✓ TinyML deployment on edge devices
- ✓ 60-80% bandwidth reduction via semantic communication
- ✓ Digital Twin for real-time simulation (small case)
- ✓ Ultra-low latency (<50ms) operations
- ✓ Energy-efficient edge computing

WP3: INTELLIGENT CYBERSECURITY
- ✓ AI-driven threat detection and prevention
- ✓ 5G/6G network compatibility
- ✓ Blockchain for data integrity
- ✓ Explainable AI (XAI) for security reliability

Conclusion & Future Prospects

Project Vision

Transform ASEAN agriculture through intelligent, autonomous IoT systems that integrate expert knowledge, enable real-time decision-making, and ensure robust cybersecurity—all accessible across linguistic and resource boundaries.

Key Achievements

✓ Multimodal MoE with multilingual RAG-LLM

✓ Autonomous edge control systems/ semantics comms

✓ Intelligent 5G/6G cybersecurity

✓ Cross-ASEAN collaboration framework

Future Directions

→ Satellite imagery integration

→ AI-powered crop breeding

→ Carbon credit trading systems

→ Expansion to more ASEAN languages

This project addresses critical food security and environmental sustainability challenges while supporting ASEAN ICT Master Plan objectives through innovative, scalable, and inclusive smart agriculture solutions.

Thank You for Your Attention

Questions & Discussion