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具AI Agent優化決策之智慧水族箱系統

Smart Aquarium System with AI Agent-Enabled Decision Optimization



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研究領域

智慧物聯網系統設計與應用、人工智慧、嵌入式系統。

作品摘要

觀賞魚飼養已成為現代人重要的療癒休閒方式，然而水質管理涉及酸鹼值(pH)、氧化還原電位(ORP)、溫度與電導率(EC)等多項專業參數，而一般飼養者常因缺乏知識導致魚隻死亡率偏高。市面上現有的智慧水族箱多數僅能提供感測數據監控，或仰賴單純的固定閾值(Threshold-Based)進行自動化控制，無法應對多變量交互影響的複雜水質變化，缺乏主動協助使用者進行決策的智慧化能力。

為解決此問題，我們提出「具AI Agent優化決策之智慧水族箱系統」，整合了人工智慧物聯網(AIoT)、雲端運算與大型語言模型(LLM)，目的是為了打造出具備「感知(Perception)、推理(Reasoning)與執行(Action)」三位一體能力的智慧決策架構與系統。

在環境感知與執行層面，本系統採用ESP32作為邊緣運算核心，ESP32內建Wi-Fi/藍牙雙模，且在多模態數據採集上具備極高的I/O靈活度，它讓我們在維持低建置成本的同時，保留了將運算推向邊緣層的餘裕，實現水質參數與水位資訊的即時採集，為上層數據分析提供高可靠度的基礎。

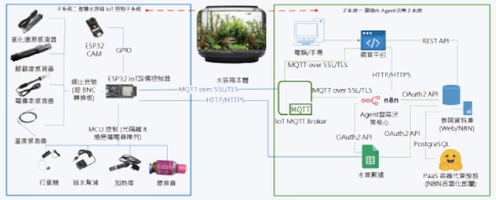
本系統最核心的創新在於雲端部署的階層式多代理人系統，系統將複雜決策拆解，主要由三大類代理人協同運作：

User Agent：負責情境感知，能理解用戶的自然語言請求與設定，並進行任務規劃與主動進行維護與建議。

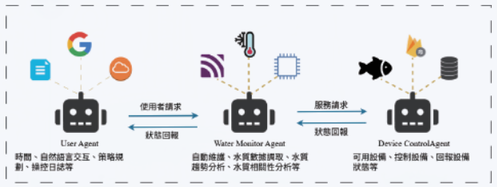
Water Monitor Agent：負責處理資料，可以針對當下與過往的時序數據進行分析，計算水質趨勢與參數間的相關性等。

Device Control Agent：作為Agent的手腳，將系統決策轉化為實體控制指令以驅動實體設備，提供系統操控實務的能力。

系統結合了規則引擎與LLM的混合推理架構，不僅能處理簡單的數值越界，面對複雜情境時更能自動分析異常原因，並給出具可解釋性的專家建議。另外本系統提供多模態自然語言互動介面，讓使用者可直接透過文字或上傳魚隻照片進行診斷，大幅降低操作與學習門檻，也提供簡單易懂的操作方式，本作品成功將傳統「數據監測」轉型為「智慧決策」應用，未來亦具備推廣至智慧水產養殖與寵物照護領域的龐大發展潛力。



圖一 系統架構圖。



圖二 系統流程圖。

Abstract

Ornamental fish keeping has become a popular recreational activity, yet water quality management, encompassing pH, oxidation-reduction potential (ORP), temperature, and electrical conductivity (EC), remains technically demanding for general hobbyists. Existing smart aquarium systems are largely limited to monitoring sensor data or to simple threshold-based automation, and lack the intelligence to address complex, multi-variable water quality dynamics or to actively assist users in decision-making.

To address this gap, we propose an AI Agent-Optimized Smart Aquarium System that integrates Artificial Intelligence of Things (AIoT), cloud computing, and large language models (LLMs) into a unified architecture embodying Perception, Reasoning, and Action. An ESP32 microcontroller serves as the edge computing core, enabling real-time acquisition of water quality parameters and water level data at low deployment cost.

The central innovation of this system is a cloud-deployed hierarchical multi-agent framework in which three specialized agents collaborate: The User Agent handles context-aware natural language interaction and proactive maintenance recommendations; the Water Monitor Agent performs time-series analysis and inter-parameter correlation to identify trends and anomalies; and the Device Control Agent translates decisions into physical control commands for actuating hardware devices.

The system employs a hybrid reasoning architecture that combines a rule engine with LLM-based inference, enabling it to handle not only threshold violations but also complex anomalies, delivering interpretable, expert-level diagnostic guidance. A multimodal interface further allows users to submit text queries or upload fish photographs for diagnosis, significantly lowering the barrier to entry. A functional prototype has been implemented, demonstrating that integrating LLM-based multi-agent reasoning with low-cost IoT hardware is a viable approach to transforming passive data monitoring into active, intelligent decision-making with clear potential for extension into smart aquaculture and broader pet care applications.

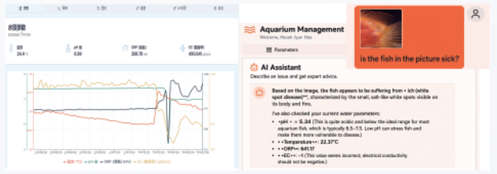


Fig. 3 User interface.



Fig. 4 Overall view of the smart fish tank and its webpage presentation.