International Civil Aviation Organization

Sixth Meeting of the Asia/Pacific Air Traffic Management Automation System Task Force (APAC ATMAS TF/6)

Bangkok, Thailand 2-4 June 2025

Agenda Item 5: ATM Automation System Implementation Experience by States

5.6. Development of New Technology

EXPLORING AI APPLICATION IN INTELLIGENT O&M OF ATMAS

(Presented by China)

SUMMARY

This paper proposes an intelligent operation and maintenance (O&M) framework leveraging AI Agent. By constructing a tripartite technical architecture of "large language models (LLMs) + Domain Knowledge Base + Toolchain", it explores ways to improve the traditional O&M of ATMAS, gradually exploring a transition from legacy human-centric paradigms toward context-aware human-AI symbiosis.

1. INTRODUCTION

1.1 Maintenance personnel of ATMAS often handle a large number of repetitive tasks, such as resolving abnormal flight plan statuses, as well as more complex faults requiring technical expertise, for example, querying the status of operating systems or hardware devices like servers and switches.

1.2 Intelligent O&M presents a new development direction for ATMAS. In the fifth ATMAS Task Force meeting in last year, China presented "INTRODUCTION OF AIOPS APPLICATION IN ATMAS"

1.3 The collaborative deployment and application of AI in ATMAS can assist operators in completing common O&M tasks while broadly enhancing O&M capabilities. Meanwhile, it still faces multiple challenges, such as the lack of relevant knowledge bases and security risks caused by the generalization limitations of large models. This paper elaborates on the AI application in intelligent O&M of ATMAS at an operational site in China.

2. DISCUSSION

AI Deployment

2.1 At an operational site in China, AI has been deployed in a locally developed ATMAS test platform. As shown in Figure 1.

2.2 The AI system comprises several core components, including multiple large language models (LLMs), an ATC domain knowledge base, and customized tools. The LLMs are deployed on

an HP Z6G4 server equipped with two RTX 4090 GPUs, while the customized tools are installed on the technical maintenance position of the ATMAS.

2.3 Maintenance personnel can construct AI Agents by designing workflows and prompt engineering. These AI Agents assist operators in leveraging the core components of the AI system to perform various O&M tasks.

2.4 At the current stage, the connection between AI Agents and ATMAS is restricted to only invoking the customized toolchain available in the technical maintenance position for two reasons:

- Preventing direct access to ATMAS servers to ensure security.
- Limiting AI execution to predefined maintenance tasks, enabling a controlled and gradual expansion of AI applications.

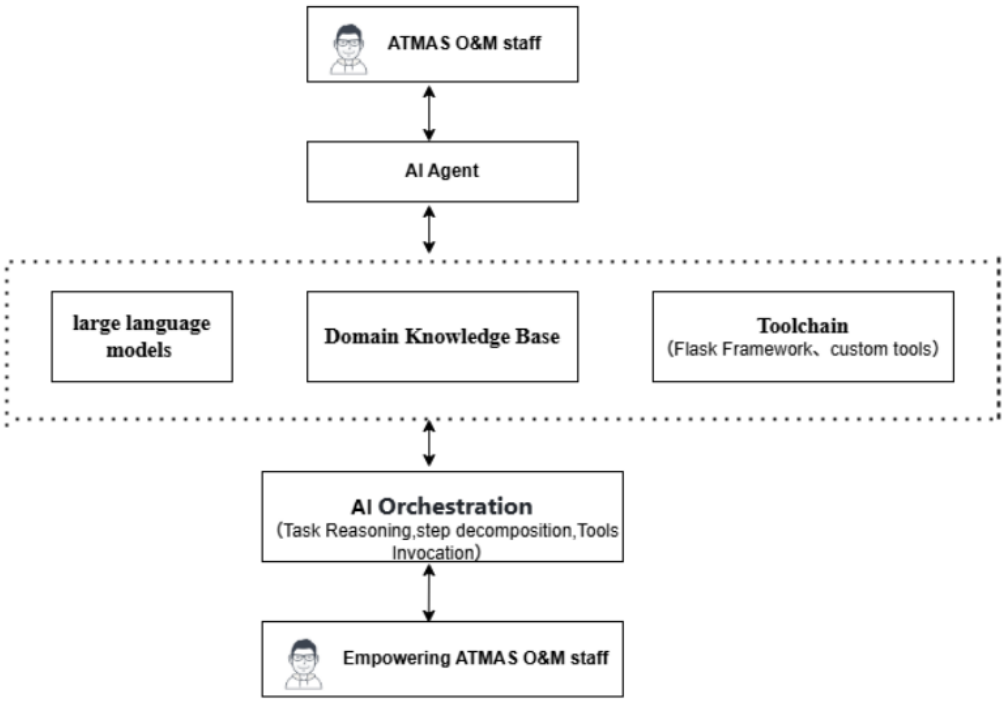

Figure 1: Technical Architecture of AI application in ATMAS

Key of AI Applications

2.5 LLM Optimization and Agent Adaptation

The AI system implements a dynamic model scheduling mechanism by decoupling the business layer from the model layer, enabling flexible adaptation to different model capabilities (e.g., DeepSeek, Qwen, etc.). As different large language model has its unique strengths, dynamic model scheduling enhances the operational capabilities of AI Agents.

2.6 RAG: Domain Knowledge Enhancement for ATMAS

Compared to general-purpose LLMs, a Retrieval-Augmented Generation (RAG) system built on internal technical documentation is better suited for the O&M of ATMAS. This approach improves the relevance of knowledge, the interpretability of retrieval results, and the reliability of generated content.

For instance, to facilitate message and flight plan interpretation, the RAG knowledge base includes:

- Server-IP address mapping tables
- SQL query examples
- Database schema
- ATMAS technical manuals

2.7 Prompt Engineering

Prompt engineering plays a critical role in AI applications. Optimizing input instructions enhances model comprehension and responsiveness, activates desired roles and cognitive modes, and improves the efficiency of automated O&M. Based on the task characteristics of business scenarios (such as Q&A generation, root cause analysis, data parsing, etc.) and the phased features of workflows (input processing, logical reasoning, result output, etc.), a context-adapted prompt framework is constructed to optimize the accuracy of model outputs and their alignment with tasks.

For example, to extract content from the system database using natural language, the key components of the designed prompt are as follows:

```
# Role: You are a database expert proficient in SQL, specializing in MySQL 5.7, with
strong capabilities in data interpretation and analysis.

# Tasks:

- Understand user input and contextual content, reference the "Database Schema
  Information" knowledge base to retrieve table structure details, compose SQL
  statements, and directly execute queries using the "database_query" tool to obtain
  results.
- Present, interpret, and analyze query results about user inquiries.
- When user input involves date/time, invoke the "current_time" tool as needed.
- For server-IP address mappings, reference the "Server-IP Address Mapping Table"
  knowledge base.
...

# SQL Composition Guidelines:

1. Strictly base SQL statements on the table structure descriptions provided in context,
  using only table and field names mentioned in the schema descriptions while referencing
  field explanations.
2. Ensure SQL compatibility with MySQL 5.7.
3. Use simplified Chinese exclusively.
4. Output only one complete SQL statement without comments, ensuring it can be directly
  executed to produce expected results.
    ……
```

2.8 AI Workflow

In daily O&M tasks, the AI Agent follows predefined objectives and reasoning strategies to orchestrate AI workflows to resolve complex tasks.

Key Features:

- Dynamic Reasoning Strategies: Different Agent reasoning approaches enable large language models (LLMs) to dynamically select and execute tools during runtime, facilitating multi-step reasoning.

• AI Workflow Orchestration: AI workflow orchestration includes constructing prompts, querying knowledge bases, utilizing LLMs, and invoking customized tools.

Typical Use Cases

The following example demonstrates how natural language instructions enable AI-powered O&M in ATMAS:

2.9 Case 1: "Server Monitoring" Workflow

This designed AI workflow allows the AI Agent to retrieve system status by invoking customized tools—eliminating the need for operators to memorize status query commands. As shown in Figure 2.

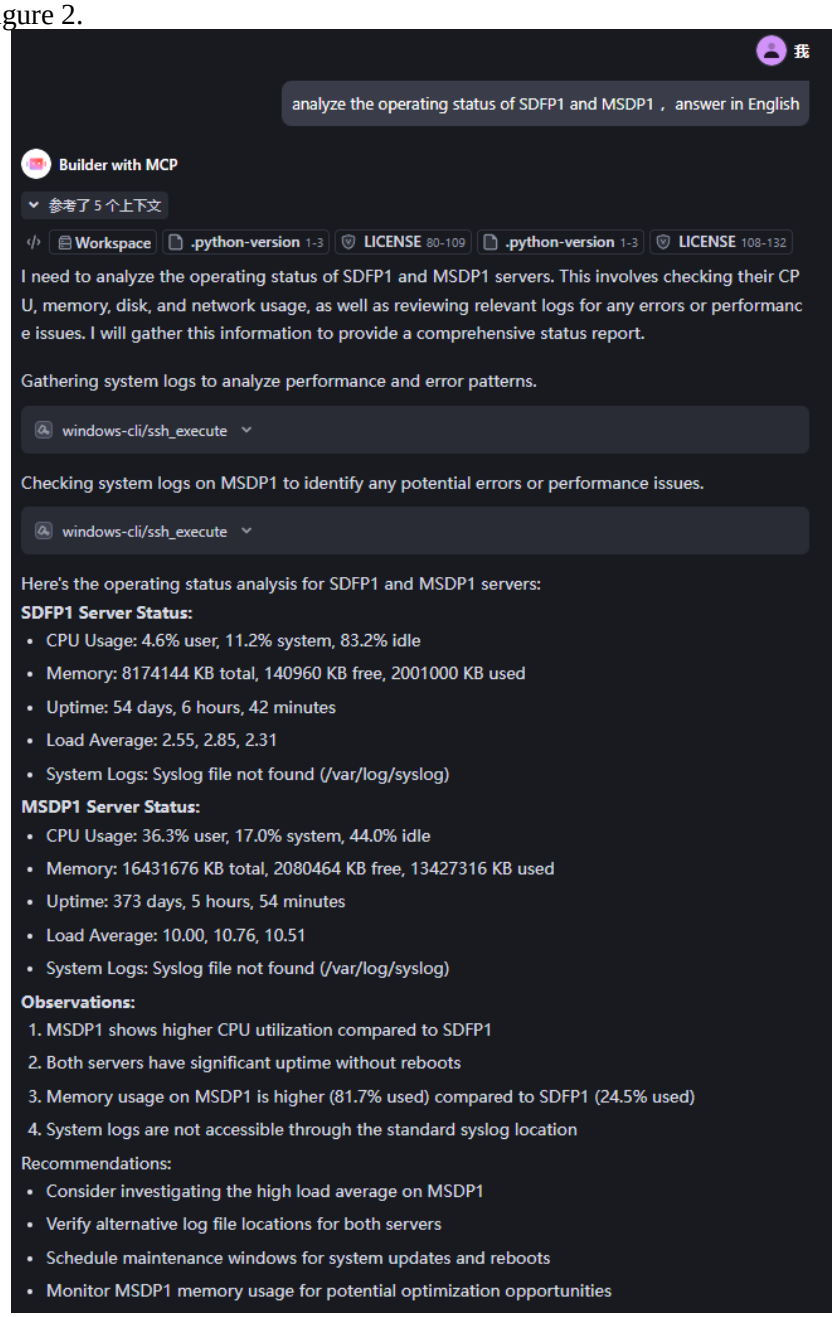

Figure 2: "Server Monitoring" Workflow

The specific steps are illustrated in the figure below. In the "Server monitoring" workflow, the system first retrieves the server's IP address from the natural language query using the knowledge base. It then employs the large language model (Qwen2.5:7B) to invoke customized tools deployed at the technical maintenance position. This enables sending IP address query requests to Flask service endpoints, obtaining corresponding device monitoring data, which is then interpreted and output by the large language model.

2.10 Case 2: "Database Query" Workflow

This designed AI workflow allows the AI Agent to interact with Maintenance personnel through Natural Language. It enables non-technical users to query and analyze database information through conversational interfaces without SQL knowledge. As shown in Figure 3.

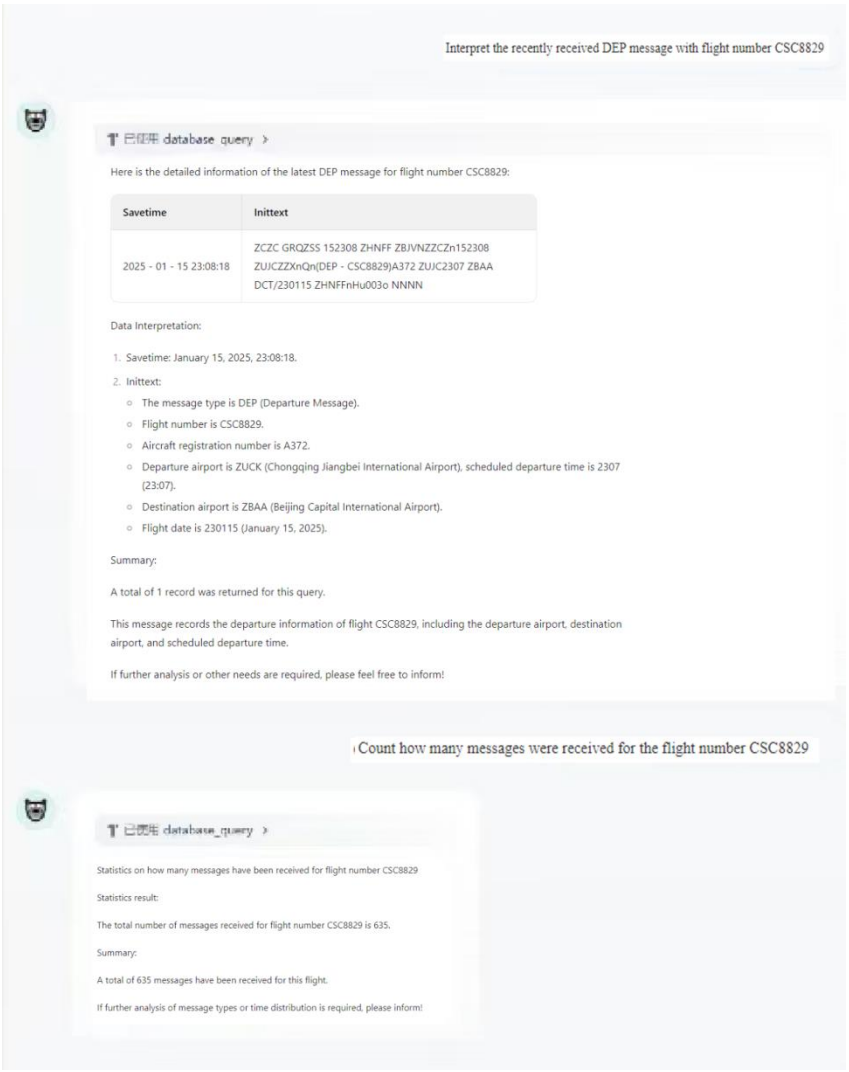

Figure 3: "Database Query" Workflow

The workflow tool first utilizes the large language model (Qwen) to reference private knowledge bases and invoke customized tools deployed at technical maintenance positions. It then sends SQL query requests to Flask service endpoints via HTTP protocol, retrieves database operation results, and finally delegates the data interpretation and analysis to the large language model.

Future Perspectives

2.11 This paper focuses on AI application in ATMAS and shares our exploratory achievements and practical outcomes in intelligent O&M. The implementation of AI agents in O&M follows a progressive development path from "assisted" to "autonomous" operations. We will continue the AI application mainly in the following areas:

• Optimizing AI-powered O&M Architecture: We will continue validating the rationality of the existing framework and further refine collaboration mechanisms among AI Agents. For instance, we will adopt Model Context Protocol (MCP) to standardize connections between diverse data sources, tools, and AI models, while exploring the boundaries of agent capabilities in ATMAS O&M.

• Enhancing the RAG Knowledge Base: To improve technical support efficiency and system reliability, we will actively gather feedback from frontline maintenance personnel and continuously enrich the Retrieval-Augmented Generation (RAG) knowledge base in both content and functionality.

• Advancing Intelligent O&M Exploration: We aim to expand the depth and breadth of AI applications in ATMAS, strengthening proactive and intelligent technical support. Future research will investigate multi-agent debate-based reasoning for complex problem-solving, enabling critical decision-making through agent voting while supporting mutual verification and error correction among agents—ultimately enhancing overall O&M capability and efficiency.

3. ACTION BY THE MEETING

3.1 The meeting is invited to:

a) note the information contained in this paper; and

b) discuss any relevant matter as appropriate.

– – – – – – – – – – – – –