Project Title: ReACT AI Agents for Human-Machine Collaboration in Industrial Automation

Brief Description of the Project: This project enhances industrial automation through ReACT (Reasoning and Action) AI agents, which integrate large language models (LLMs) with actionable execution. These agents analyze and plan industrial processes, making real-time decisions to support flexible and reconfigurable production systems. The AI agent facilitates Human-Machine Collaboration by enabling direct interaction with machines through natural language, leveraging LLM-based reasoning to analyze tasks and execute actions via OPC UA for dynamic and efficient industrial operations.

What Problem Does Your Project Aim to Solve? Traditional industrial control systems rely on rigid, predefined sequences of operations, requiring manual intervention for reconfiguration. This approach leads to inefficiencies, increased downtime, and limited adaptability to changing requirements. Our project addresses these challenges by introducing AI-driven automation that enables intelligent decision-making, real-time adjustments, and dynamic process adaptation, thereby reducing human workload and optimizing industrial operations.

Why Do You Think Generative AI Provides Value in Solving This Problem? Generative AI enhances industrial automation by:

- **Dynamic Adaptation:** AI agents can interpret human queries, plan actions, execute them, and analyze real-time feedback while dynamically reconfiguring industrial processes.
- **Human-Machine Collaboration:** The AI agent enables intuitive interaction between operators and machines through natural language processing.
- **Skill Sequencing:** The AI determines the optimal sequence of operations, reducing dependency on predefined scripts.
- **Error Handling:** Feedback from machines is provided in real time to the LLM, enabling it to reason whether to modify, repeat, or adjust execution steps dynamically for improved error handling and process optimization.
- **Scalability:** The AI-driven approach allows for seamless integration of new skills and components, making automation systems more flexible and future-proof.

Expected Outcome of the Project:

- Develop a control system integrated with IEC 61499-compliant modular automation for a machine residing in the lab, specifically the Processing Station consisting of three components: a Rotating Table, a Tester Component, and a Drilling Station. (Completed)
- Develop a robust skill execution framework and enable OPC UA for skill execution, allowing the AI agent to invoke machine skills via OPC UA for seamless and automated industrial operations. (Completed)
- Develop a ReACT AI agent model that integrates reasoning capabilities with real-time decision-making. The agent will leverage large language models (LLMs) to interpret tasks, plan

execution steps, and dynamically adjust actions based on real-time feedback from industrial processes. (Completed)

- Develop and analyze a control system for a distributing station machine, where the AI agent interacts with a simulation model for evaluation before real-world testing in a manufacturing setting. (Completed)
- A prototype where the AI Agent enables human-machine collaboration in a manufacturing setting by reasoning and executing tasks dynamically. (In Progress)
- A publishable research paper detailing the system's architecture, implementation, and performance evaluation. (Not Yet Started)

Methodology/Approach:

1. **Proposed Architectures:**
    - **Robust Skill-Based Model Framework:** A structured framework for AI-driven skill sequencing and execution, integrating OPC UA to enable seamless interaction with machine components.
    - **ReACT Agent Model :** A reasoning and execution model leveraging LLMs to interpret tasks, plan actions, and dynamically adjust execution strategies based on real-time machine feedback.
3. **Implementation Steps:**
    - Develop and integrate a control system based on IEC 61499-compliant modular automation for a machine in the lab, including the Processing Station with a Rotating Table, Tester Component, and Drilling Station.
    - Build a robust skill execution framework with OPC UA support, enabling seamless machine skill invocation by the AI agent.
    - Develop a ReACT AI agent that integrates LLM-driven reasoning, real-time decision-making, and dynamic process adaptation.
    - Design and analyze a control system for a distributing station machine where the AI agent interacts with a simulation model before real-world deployment.
4. **Timeline:**
    - **Phase 1 (Completed):** Defined system requirements and successfully integrated the AI agent with function block-based automation.
    - **Phase 2 (Completed):** Developed a robust skill execution framework, enabling OPC UA support for AI-driven machine skill invocation.
    - **Phase 3 (Completed):** Designed and analyzed a control system for a distributing station machine where the AI agent interacts with a simulation model.
    - **Phase 4 (till week 4 (ongoing)):** Developed and tested a prototype in a real manufacturing setting, ensuring seamless AI-agent interaction with physical systems. **
    - **Phase 5 (Week 4-8):** Conduct evaluation of the AI agent's performance, validate its decision-making accuracy, and optimize execution strategies.
    - **Phase 6 (Week 6-12):** Complete research documentation, finalize experimental findings, and submit the research paper to an IEEE conference.

5. **Whether you have already started working on this**
   Yes, we have already started working on this project. Several key phases have been completed, including defining system requirements, integrating AI with function block-based automation, developing a skill execution framework, and testing a prototype in a real manufacturing setting. The remaining tasks include refining the AI agent to enhance reasoning and execution capabilities, followed by its evaluation to validate performance, optimize decision-making accuracy, and finalize the research paper for publication.

Publication Plan:

- Submit a research paper to an IEEE conference upon project completion.
- Showcase project results through live demonstrations and GitHub documentation.

Project Docs & Links

- Presentation Slides : LTU IEC 61499 AI AGENTS.pptx
- Recording & presentation : https://kdrive.infomaniak.com/app/share/1238794/7f2d8ab7-45b5-42a0-9547-de014415ab0b
- GitHub Repo : https://github.com/midhunxavier/IEC61499-AI-Assistant

Project Abstract (Optional): This project enhances industrial automation through ReACT (Reasoning and Action) AI agents, which integrate large language models (LLMs) with actionable execution. These agents analyze and plan industrial processes, making real-time decisions to support flexible and reconfigurable production systems. The AI agent facilitates Human-Machine Collaboration by enabling direct interaction with machines through natural language, leveraging LLM-based reasoning to analyze tasks and execute actions via OPC UA for dynamic and efficient industrial operations. This approach minimizes downtime, optimizes process adaptability, and offers a flexible production framework for industrial automation.