Case Study: Empowering Orthopedic Surgeons with Agentic AI for Musculoskeletal Simulation

Client Overview

A leading non-profit public benefit organization advancing research in regenerative medicine, focused on developing biological materials for tissue and organ implantation. The organization is led by senior bioengineers, clinicians, and academicians with multidisciplinary expertise in orthopedics, blood circulation, tissue engineering, and biomedical instrumentation.

Challenge

One of the client's core research areas is orthopedics, where musculoskeletal simulation plays a vital role in treatment planning and diagnosis. Orthopedic surgeons use the **AnyBody Modeling System** to simulate musculoskeletal dynamics. However, the scripting involved in AnyBody's proprietary language is highly technical, time-consuming, and typically requires programming expertise.

As most orthopedic surgeons are medical professionals without coding backgrounds, this created a heavy dependency on technical experts for script development. The client wanted to democratize the scripting process by enabling surgeons to generate simulation-ready scripts by simply describing their requirements in natural language.

Solution: Agentic AI System for Script Generation

To address this challenge, we designed and implemented an **Agentic AI system** that enables surgeons to generate accurate AnyBody scripts from natural language inputs.

System Architecture

The solution was a **hierarchical multi-agent architecture** using LangGraph, consisting of:

- **Planner Agent (Master Agent)**: Interprets the surgeon's natural language prompt, understands context, and coordinates task execution
- **Sub-Agents**:
    - **Segment Generator Agent**
    - **Joint Generator Agent**
    - **Muscle Generator Agent**
    - **Driver Generator Agent**
- **Code Validator & Corrector Agents**: Automatically detect and fix scripting errors

- **Code Orchestrator Agent**: Merges all generated code components into the final simulation script

Tech Stack & Frameworks

- **LLM Backbone**: Fine-tuned **LLaMA 3.0** model trained on AnyBody scripting examples
- **RAG Pipeline**: Implemented using **LangChain**, with a domain-specific **chunking strategy** and **ChromaDB** as the vector store for code snippet retrieval
- **Agent Framework**: **LangGraph** for managing the agent workflows and state transitions
- **Security & Observability**: Embedded **guardrails**, prompt filtering, and detailed **logging/monitoring** frameworks
- **Frontend**: Developed using **ReactJS**
- **Backend**: Implemented with **FastAPI**

Impact

- **Surgeon Empowerment**: Surgeons can now independently generate AnyBody scripts by describing their needs in plain English
- **Reduced Technical Dependency**: Eliminated reliance on scripting experts for day-to-day tasks
- **Faster Iterations**: Simulation scripting time reduced from hours to minutes
- **Improved Accuracy**: Reduced human errors in scripting, leading to more reliable simulation results

Conclusion

Through this Agentic AI solution, we successfully bridged the gap between complex biomechanical simulation tools and non-technical medical users. By combining domain-tuned LLMs, autonomous agent orchestration, and natural language interfaces, the client achieved a powerful leap forward in digital transformation for regenerative medicine.