Design Review 2

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Client: Dr. Reza Razavian

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Motivation & Impact

Clients Mission:

- Dr. Reza Razavian develops rehab-focused human-robot systems at NAU.
- Contribute to literature, and deepen our understanding of haptic interaction.

Why Haptics Matter:

- Robot can guide, assist, or resist movement
- Tracks how the body responds in real time
- Used in:
  - Stroke recovery (relearn reach & grasp)
  - Joint rehab (safe strength training)
  - Prosthetics training (controlled grip)
  - Balance training (fall-safe support)

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Problem We’re Solving

Old System:

- Not modular → every new study requires new code
- Hard to change tasks or parameters during a session
- Knowledge stuck in one developer’s head
- Slow to test, slow to publish, not clinic-ready

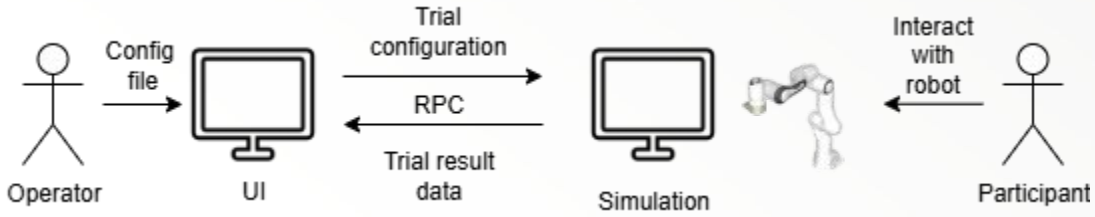
Our Work:

- Modular control + experiment blocks
- Reuse behaviors instead of rewriting them
- Makes trials faster, safer, and scalable

Solution Overview

Create a modular software system to support human-robot interaction experiments with the Franka Research 3 robot.

Problem	**Solution Feature**
No user-friendly interface.	Command-Line Interface for easy control.
No built-in data management.	Automated CSV/XML data storage.
No reusable experiment templates.	Modular architecture with XML configs.
Time-consuming setup.	Reusable, easily configurable experiments.



Key System Requirements

Domain & Functional Requirements:

- **Render 3D interactive simulations integrated with the Franka robot.**
  - Success: Smooth rendering with no visual glitches or frame drops during interaction.
- **Provide realistic, minimal delay haptic feedback.**
  - Success: Haptic control loop maintains ≤ 1 ms latency.
- **Support XML-based configuration files for experiment setup.**
  - Success: Setup time reduced by ≥ 50%.
- **Enable remote operation via a networked client-server connection.**
  - Success: Trials initialize within 10 seconds.
- **Automatically collect and organize experiment data.**
  - Success: All data saved within 3 seconds after trial completion.
- **Provide a user-friendly operator interface for experiment control.**
  - Success: Operators can complete 10+ consecutive trials without errors or crashes.

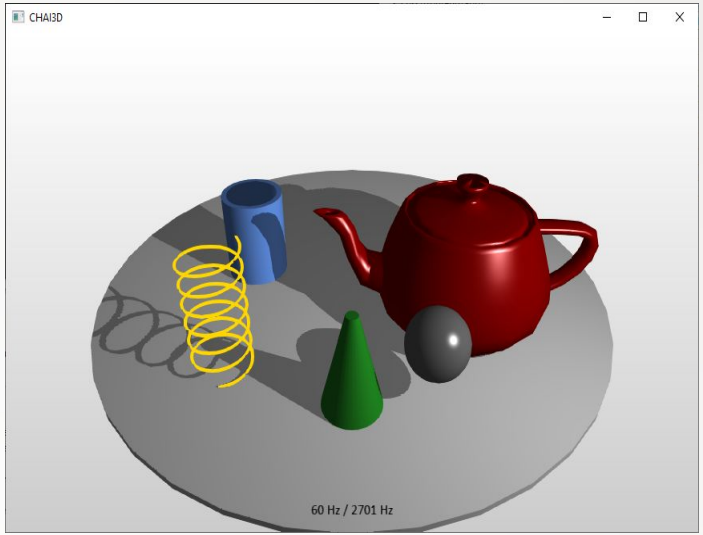
Key Risks & Owners

- **Performance (CPU Load):** System consumed entire CPU utilization; goal utilize all CPU cores for stable 1 kHz loop (Owner: Landon)
- **Data Quality:** Occasional data drops in logs; goal 0% data loss across all trials (Owner: Karissa)
- **Integration/Dependency:** Registry mismatch between modules; goal 100% successful module registration (Owner: Matt)
- **Communication Stability:** Intermittent gRPC disconnects; goal <0.5% connection loss rate (Owner: Peter)

Technology Stack

Technology:

- **C++:** real-time performance for core logic.
- **CHAI3D:** haptic rendering and 3D visualization.
- **libfranka:** robot API for Franka Research 3.
- **Python:** simple client UI.
- **gRPC:** reliable, low-latency client-server. communication.
- **CSV/XML:** lightweight, human-readable data formats.



Rationale:

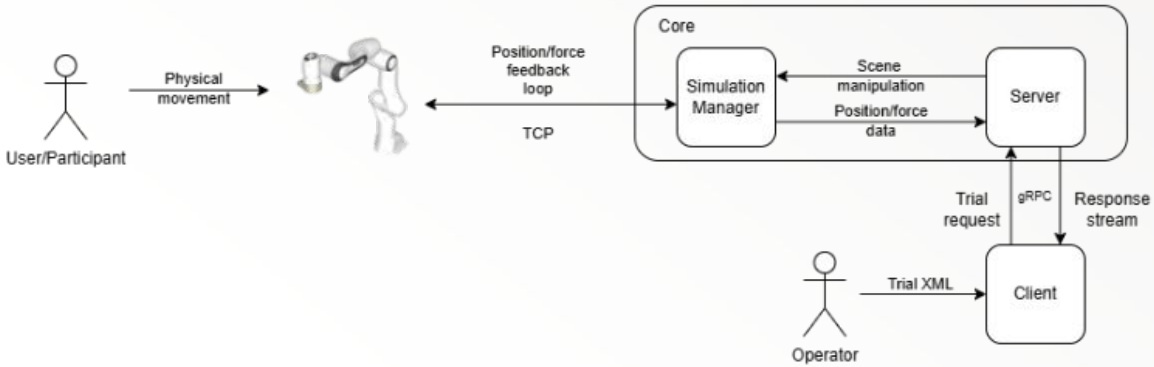
- CHAI3D & libfranka guarantee minimal delay and realistic haptics.
- gRPC enables distributed operation and scalability.
- Modular, multi-language design allows easy upgrades and reuse.

Implementation Details

System Architecture

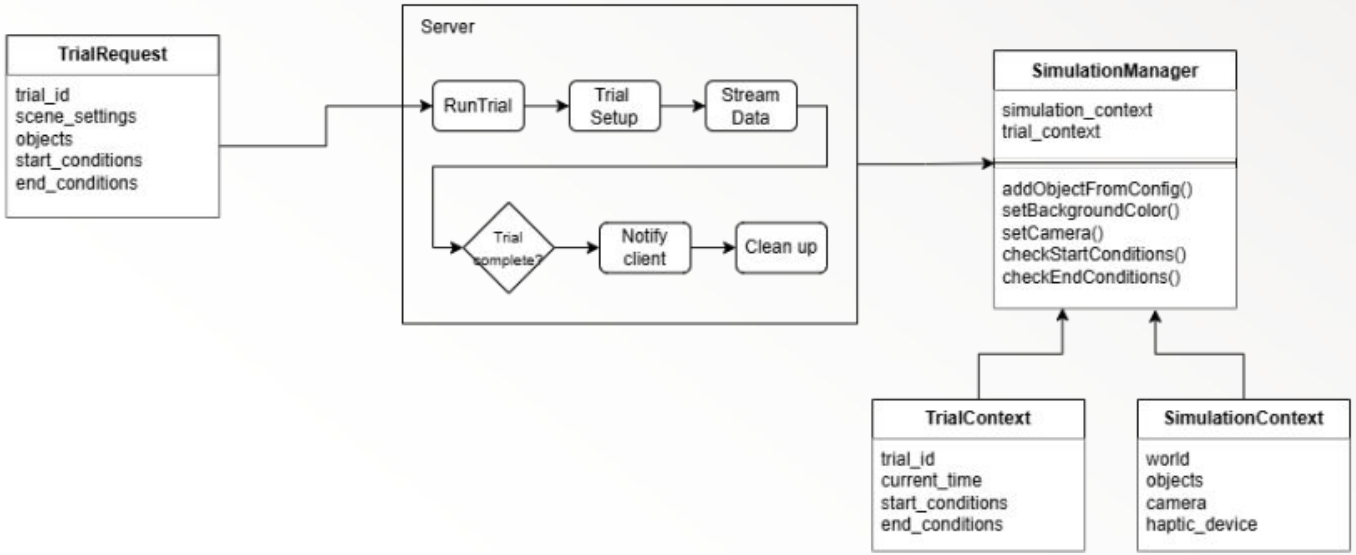
Main Components:

- **Client (UI):** Loads XML configs, run trials, manages data.
- **Server:** Parses configs, manages trials, coordinates communication.
- **Simulation Manager:** Runs CHAI3D scenes and haptic rendering.
- **Franka Integration:** Bridges CHAI3D and robot via libfranka.



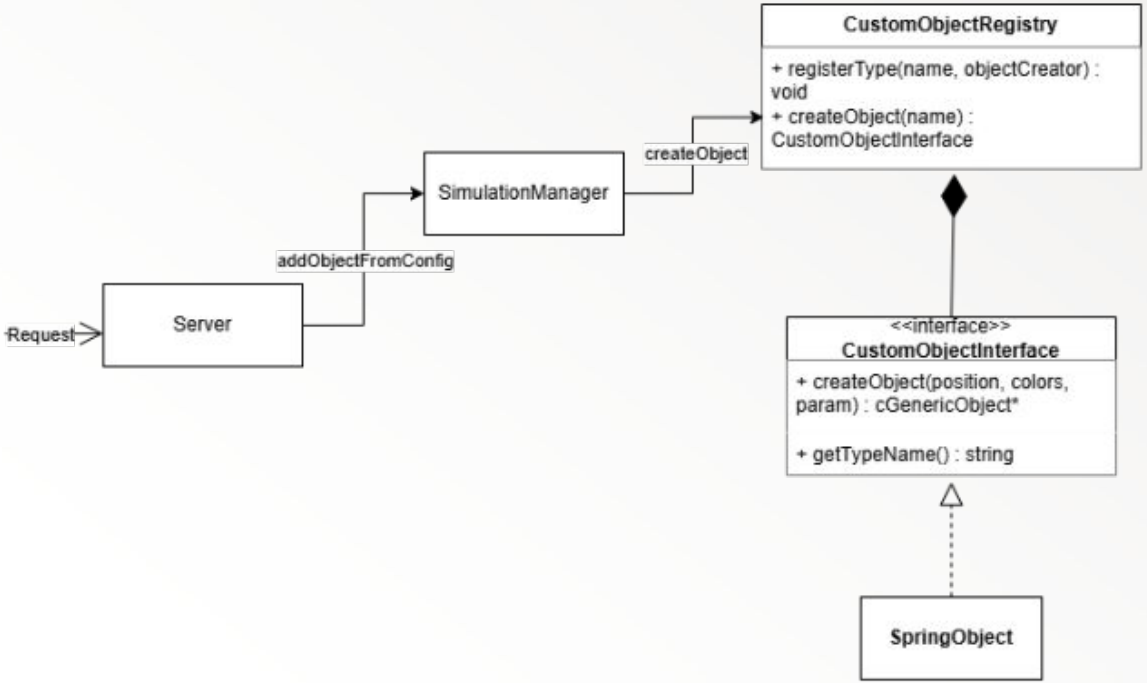
Implementation Details

Trial Flow



Implementation Details

Object Registration



Challenges and Resolutions

Segmentation Faults

Issues: CHAI3D, Simulation Manager, client/server (gRPC).

Solution: Used debugging tools.

Impact: No more segmentation faults.

Hardware Performance

Issues: Real-time & rendering saturated hardware.

Solution: Limit loops, less logging, threads.

Impact: Stable running across computer.

Runtime Crashes

Issues: Mixed source crashing.

Solution: Added debugging, proper shutdowns, code review.

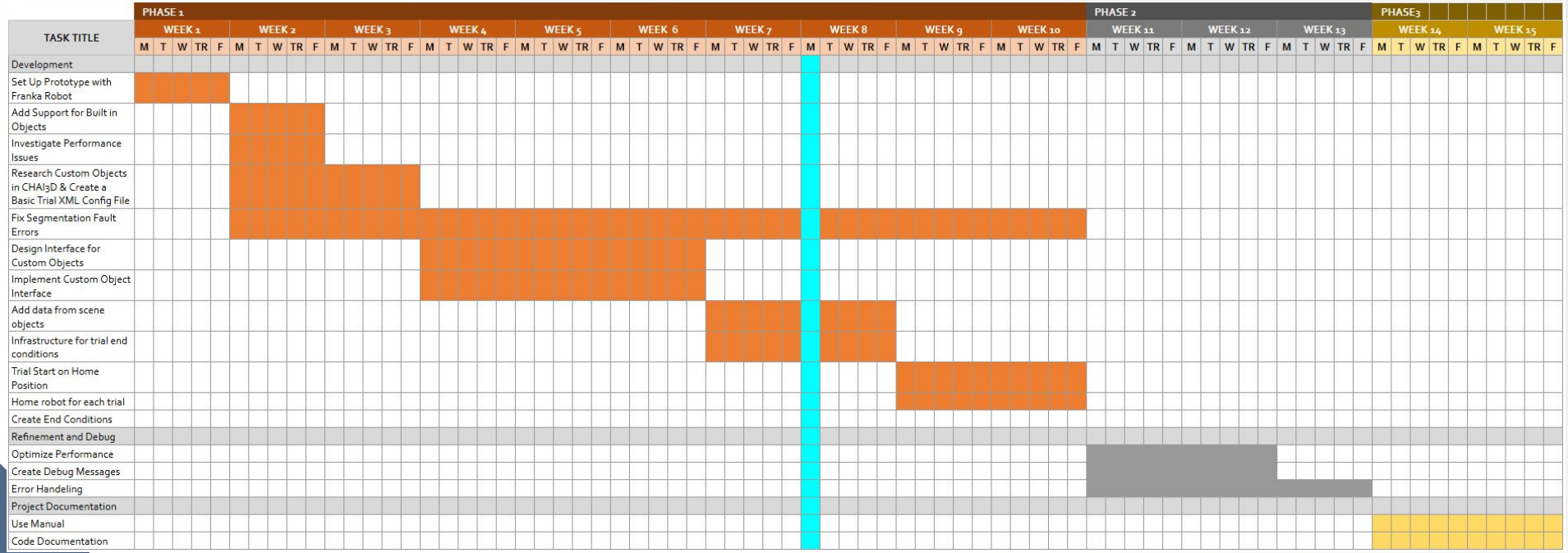
Impact: No more crashes.

Project Plan

Overall: On Track

- **Core - Simulation Manager:**
  - Complete: Scene lifestyle, object CRUD, end-condition
  - In Progress: Cursor Customization
  - Upcoming: Stability tuning
- **Core - Server:**
  - Complete: Data streaming, trial running
  - In Progress: Addition data stream control
- **CHAI3D/Franka Integration:**
  - Complete: Haptic loops
  - In Progress: Additional custom object support, Robot manual movement
- **Client:**
  - Complete: XML load, connect/start/stop, CSV logging, live data
  - In Progress: Further XML configuration
  - Upcoming: Convenience controls

Project Schedule



Conclusion

Recap:

- Haptic technology is key part of advancing human-robot interaction, especially in rehabilitation.
- Our clients current setup is limited by lack of modularity, poor accessibility, and an inefficient workflow.
- Our proposed solution is a command line user interface with a reusable experiment set up and data management.

Next Steps:

- As we near the completion of our project, our tasks have narrowed to optimization, and customization. Next we will document the project and include an extensive user manual.
- We are confident and excited to deliver a meaningful and impactful solution.
- Our hope for this project is to explore haptic robotics and push virtual reality.

Thank You!

Any questions?