HapTech

Capstone Presentation

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Client: Dr. Reza Razavian

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Why Rehab Tech & Haptics Matter

- Stroke is a leading cause of long-term disability, and about half to three quarters of survivors have lasting arm and hand problems.
- These upper limb issues make simple everyday tasks difficult
- Traditional rehab is time consuming and not efficient

Haptics & Robotics Impact

- Haptic rehab robots can guide, assist, or resist movement while sensing forces and motion in real time.
- A study published by Sage Journals found robot-assisted therapy can improve motor recovery and is at least comparable to conventional therapy for upper-limb function.
- These systems deliver consistent data and enhance practice which reduce therapist workload.

Haptic robot enhancing stroke rehabilitation

Our Client: Dr Reza Razavian

Clients Mission:

- Dr. Reza Razavian develops rehab-focused human-robot systems at NAU.
- His lab designs rehab focused robot systems, and publishes data that deepen our understanding of when robots guide, assist, or resist movement. (Sharif Razavian, 2025; Shirley Ryan AbilityLab, 2024)

The Problem

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

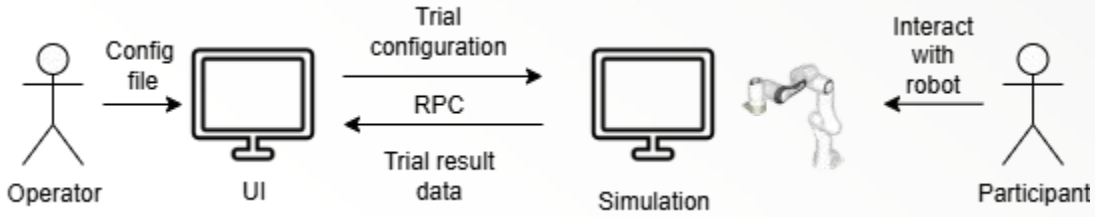
Our Work:

- 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.



System Requirements

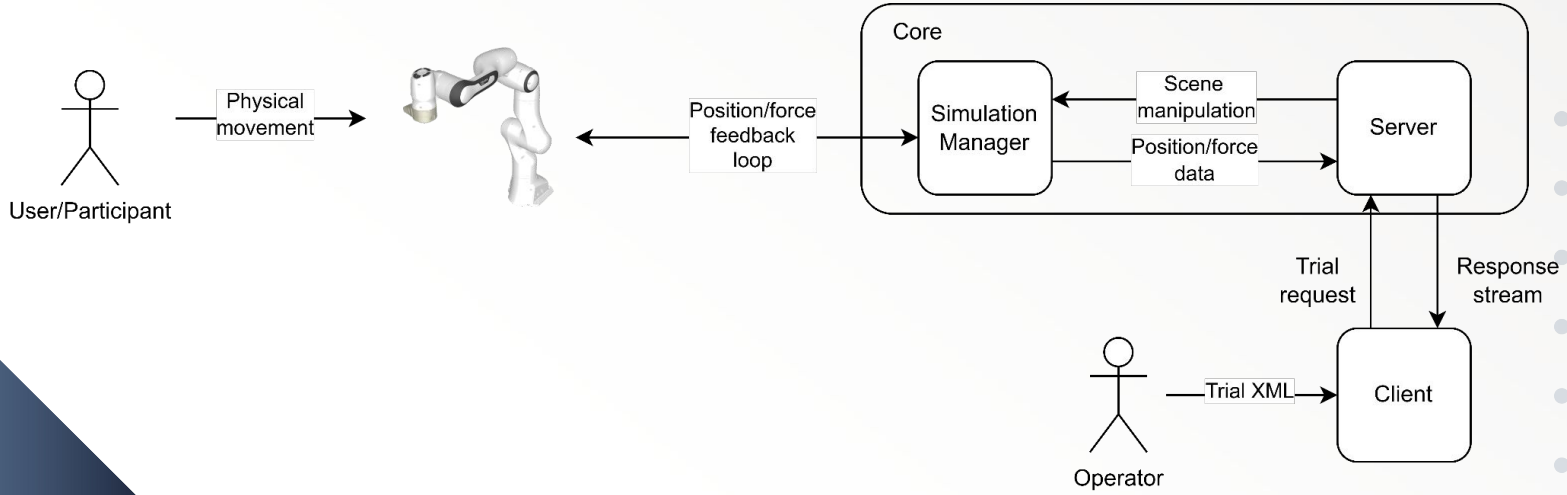
1. **Render 3D interactive simulations integrated with the Franka robot.**
   - Success: Smooth rendering with no visual glitches or frame drops during interaction.
2. **Provide realistic, minimal delay haptic feedback.**
   - Success: Haptic control loop maintains ≤ 1 ms latency.
3. **Support XML-based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

Implementation Details

System Architecture

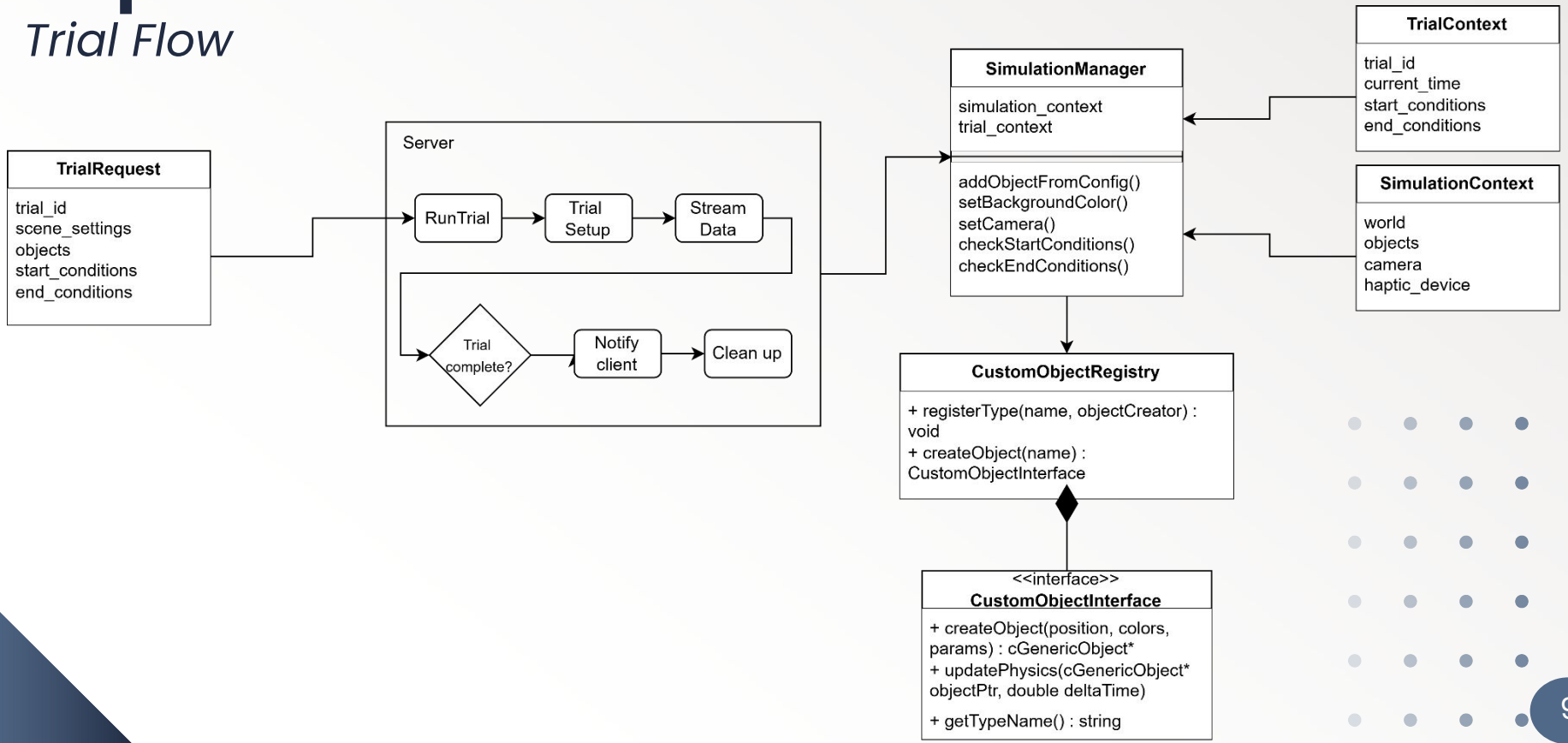
Main Components:

- **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.

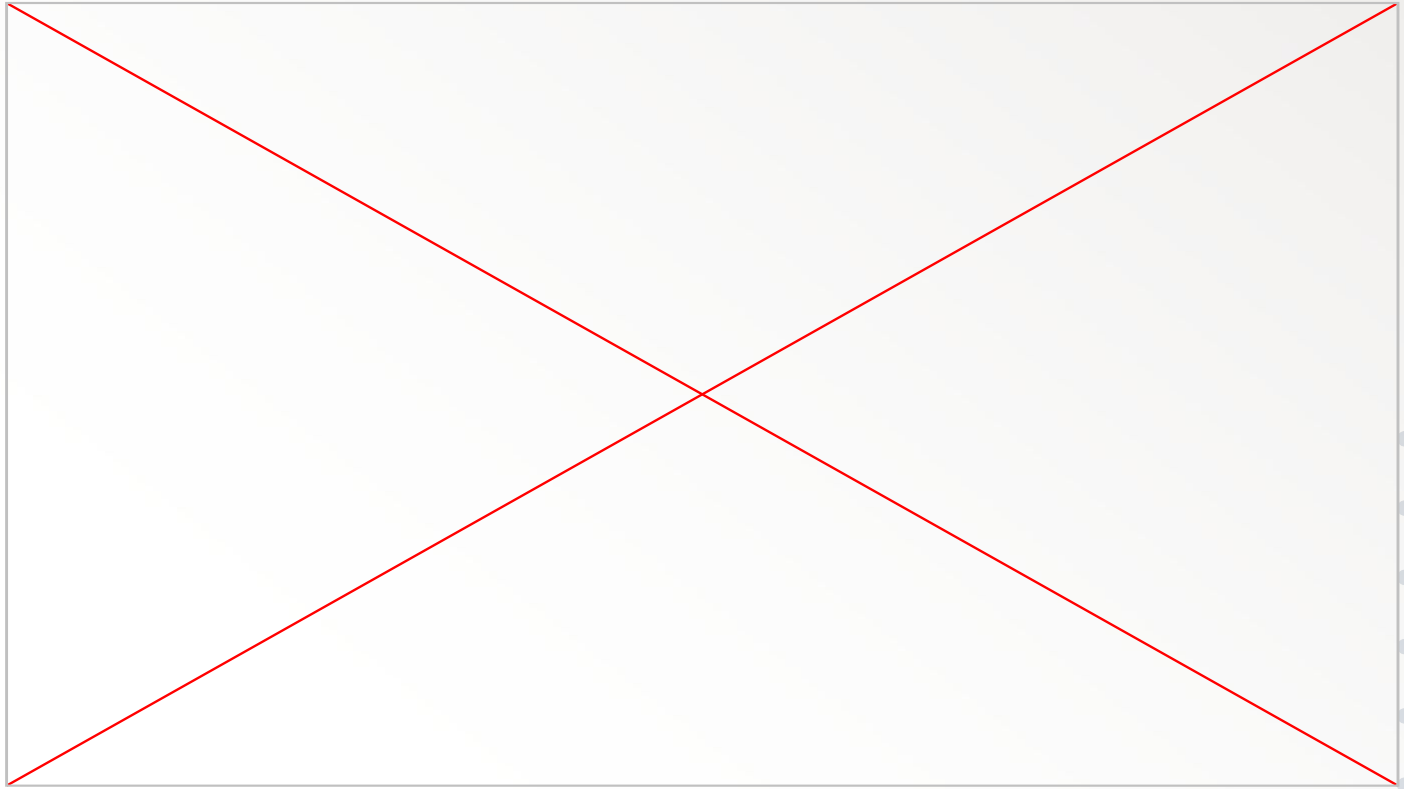


Implementation Details

Trial Flow



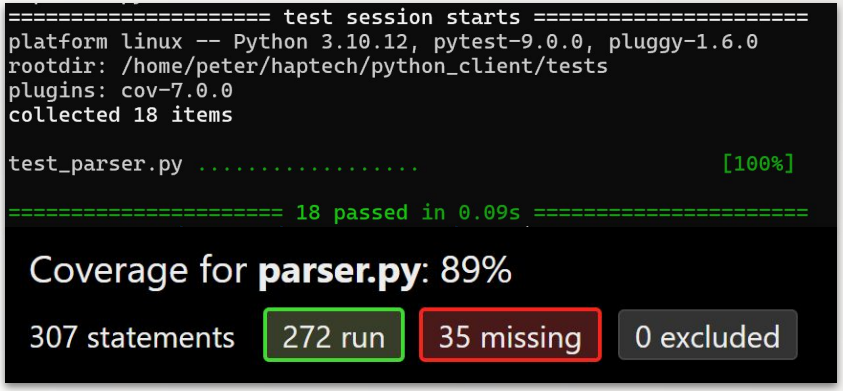
Product Review

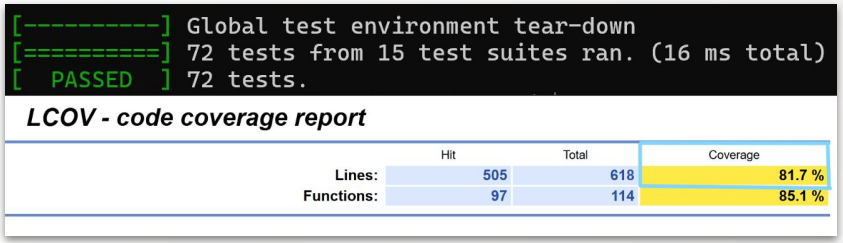


Unit Testing

- **XML Parser (Python, PyTest)**
  - 18 unit tests, 100% passing
  - 89% code coverage
- **Core (C++, GTest)**
  - 72 unit tests, 100% passing
  - 81% code coverage

- **Goals**
  - 100% of tests passing
  - >=80% code coverage of tested files
- **Issue Identified**
  - Some object implementations lacked proper handling of invalid parameters





Integration Testing

- Created and tested mock trials
- Manually tested haptic feedback
- Monitored graphic and haptic performance

- **Goals**
  - Consistently run trials successfully
  - Accurate data collection from robot and sim. environment
  - Haptic loop performance ~1000 Hz
- **Issue Identified**
  - Haptic loop dropped below 500 Hz under load

Usability Testing

- Weekly meetings with Dr. Razavian during development for feedback from user perspective

- **Actionable Feedback Gathered**
  - Need for data collection configuration
  - Need for experiment scripts in addition to single trial runs from command line

Challenges and Resolutions

Segmentation Faults

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

Solution: Used debugging tools.

Impact: No more segmentation faults.

Performance

Issues: Real-time & rendering saturated hardware. Cursor/Physics.

Solution: Limit loops, less logging, threads.

Impact: Stable running across computer.

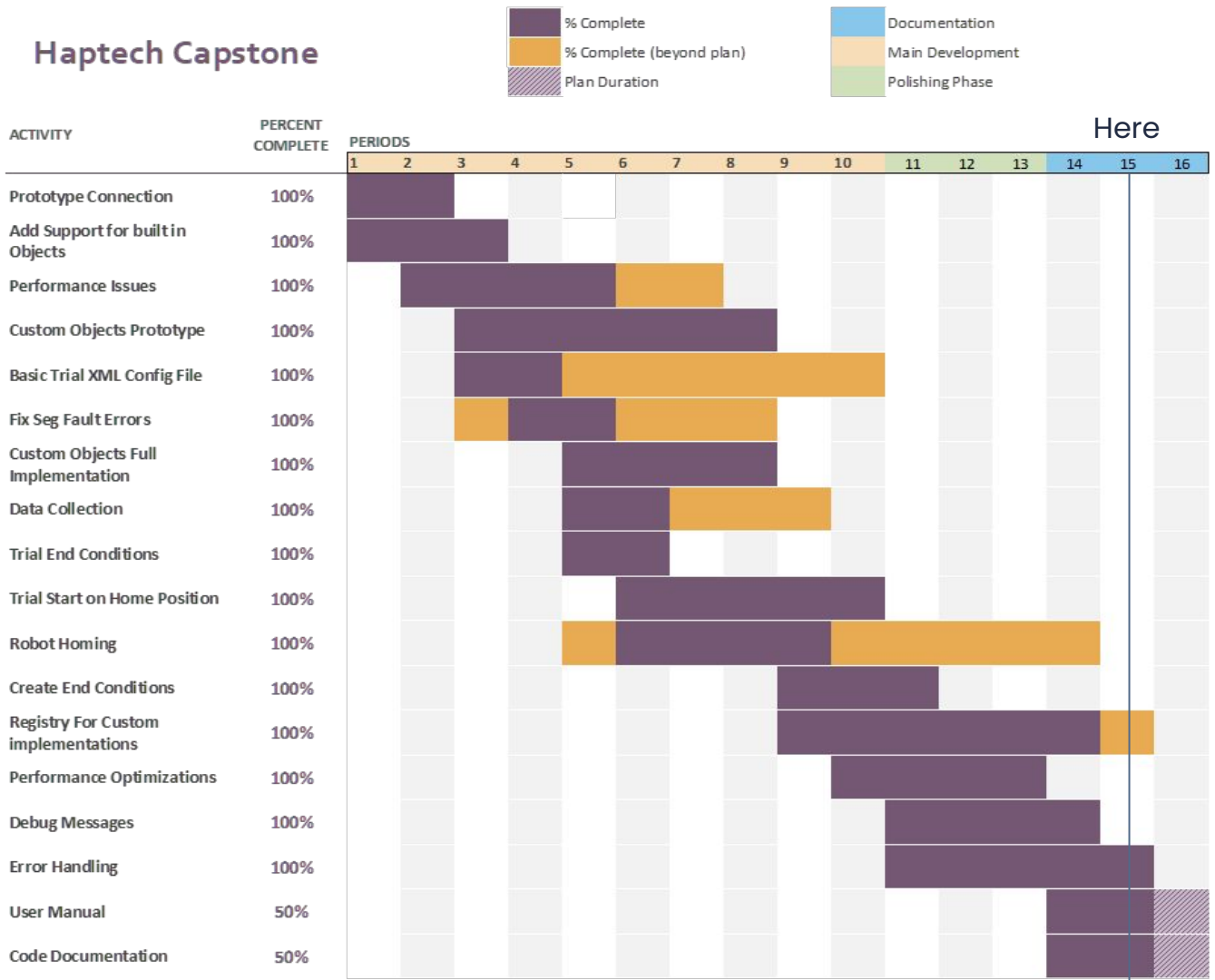
Runtime Crashes

Issues: Mixed source crashing.

Solution: Added debugging, proper shutdowns, code review.

Impact: No more crashes.

Haptech Capstone



Future Work

1. **Support for Additional Robots & Simulation Platforms:**
   - A modular hardware/simulation layer that supports additional robots and simulation platforms like Gazebo or Isaac Sim for richer virtual environments.

2. **Real-Time Visualization & Monitoring Dashboards:**
   - Live force, position, and performance graphs to observe participant behavior, improve safety, and streamline experiment debugging.

3. **AI-Driven Adaptive Experiments:**
   - Machine learning to predict user motion and dynamically adjust virtual environments or task difficulty.

Conclusion

Recap:

- Haptic technology is key part of advancing human-robot interaction
- 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:

- Document the project and finish User Manual.
- We are confident and excited to deliver a meaningful and impactful solution that helps advance the technology of Human Robot Interaction.

"You did everything I asked you to do (which rarely happens!), and I am very grateful for your efforts in this project." -Dr. Reza Razavian

Thank You!

Any questions?