HapTech

Design Review 3

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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

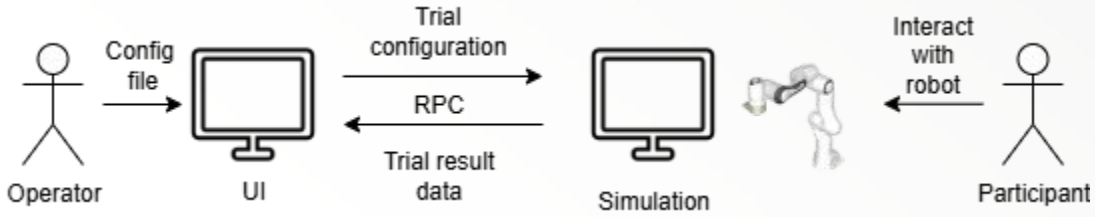
Our Work:

- 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:

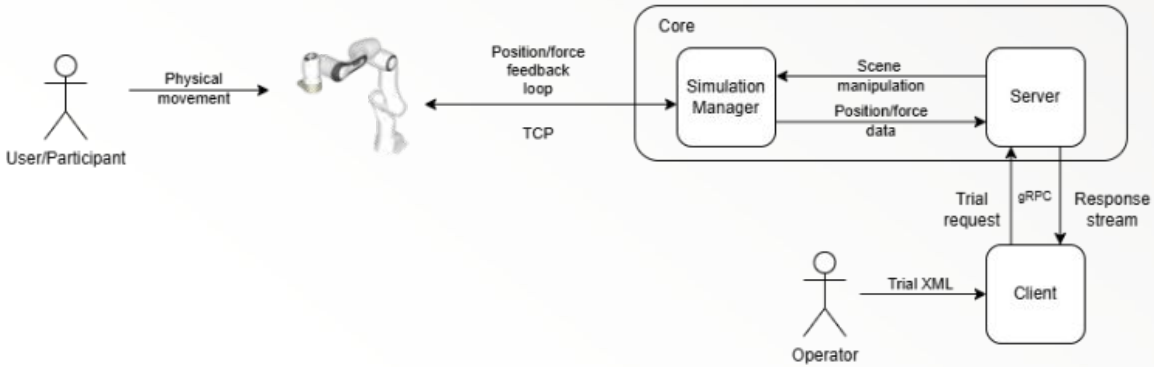
1. **Render 3D interactive simulations integrated with the Franka robot.**
   - Success: Smooth rendering with no visual glitches or frame drops during interaction.
2. **Provide realistic, minimal delay haptic feedback.**
   - Success: Haptic control loop maintains ≤ 1 ms latency.
3. **Support XML-based 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

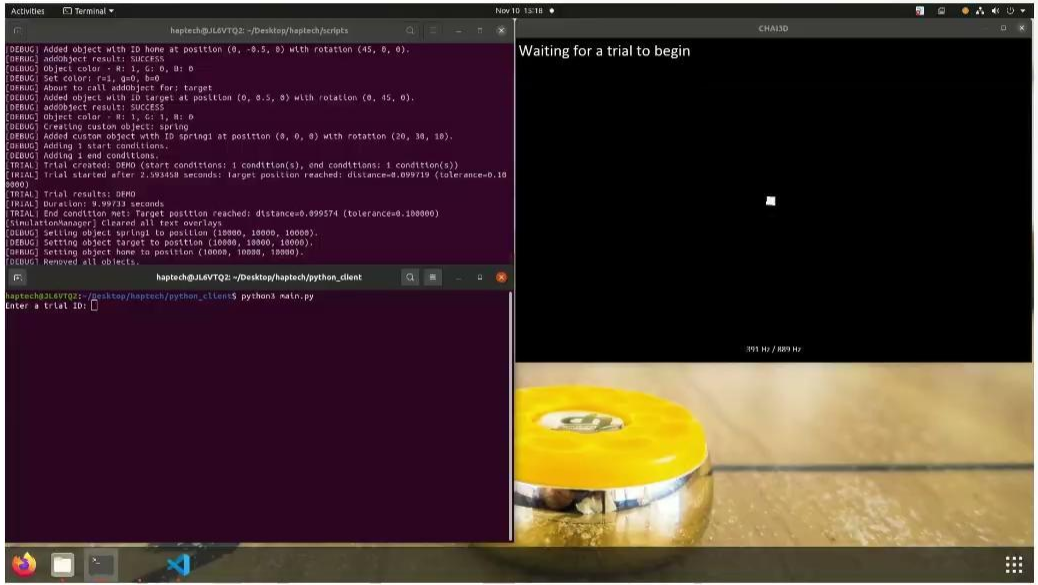
System Architecture

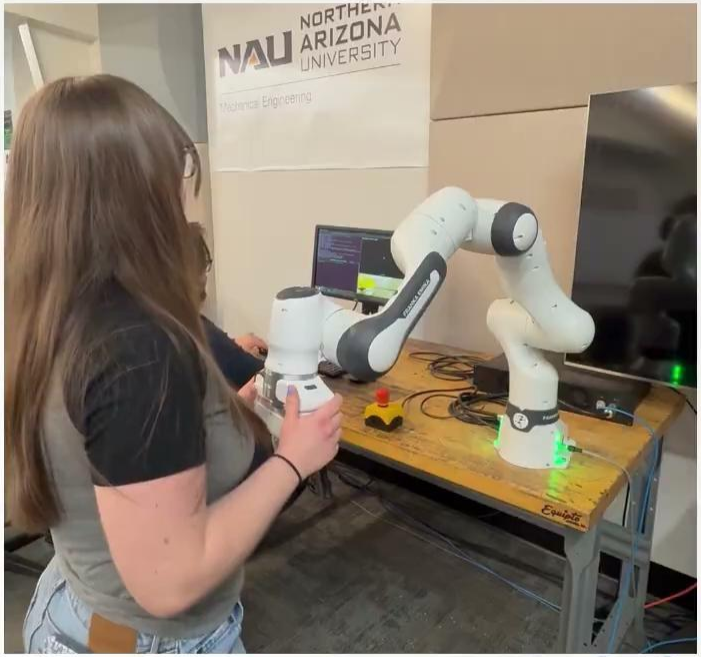
Main Components:

- **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.



Prototype Review





Testing Plan

- **Unit Testing:**
  - **Frameworks**: PyTest for Python, Google Test (GTest) for C++
  - **Scope:** Core custom object and trial condition logic, simulation manager, XML parser
  - **Goal:** 100% unit tests passing, ~80% coverage of tested files
- **Integration Testing:**
  - **Scope:** Trial lifecycle, haptic feedback
  - **Goal:** Stable user workflow & realistic, responsive, and safe robot usage
- **Usability Testing:**
  - **Expert reviews**: Evaluate UI usability
  - **User studies**: Researchers and experiment participants simulate a real lab study environment using the tool
  - **Acceptance Testing**: Verify the product meets the expectations of Dr. Razavian and his team
  - **Goal**: Gather real user feedback in order to deliver a product that actually satisfies our client's initial needs and requirements

Testing Progress

- **Current Progress:**
  - Unit testing frameworks installed and set up for the project.
  - Integration testing performed throughout development with implementation of new features.
  - High-level acceptance testing done with client throughout development.
- **Next steps:**
  - Expand coverage of unit tests.
  - More detailed integration testing of edge cases, stress testing.
  - Usability testing with more participants.

```
peter@Peter:~/haptech/python_client$ python3 -m pytest
============================================================ test session starts ==
platform linux -- Python 3.10.12, pytest-9.0.0, pluggy-1.6.0
rootdir: /home/peter/haptech/python_client
plugins: cov-7.0.0
collected 1 item

tests/test_parser.py .

============================================================ 1 passed in 0.02s ===
peter@Peter:~/haptech/python_client$
```

```
peter@Peter:~/haptech/core/tests/build$ ./core_tests
[==========] Running 8 tests from 1 test suite.
[----------] Global test environment set-up.
[----------] 8 tests from TimeConditionTest
[ RUN      ] TimeConditionTest.CreatesWithValidDuration
[       OK ] TimeConditionTest.CreatesWithValidDuration (0 ms)
[ RUN      ] TimeConditionTest.EvaluatesFalseWhenTimeNotElapsed
[       OK ] TimeConditionTest.EvaluatesFalseWhenTimeNotElapsed (0 ms)
[ RUN      ] TimeConditionTest.EvaluatesTrueWhenTimeElapsed
[       OK ] TimeConditionTest.EvaluatesTrueWhenTimeElapsed (0 ms)
[ RUN      ] TimeConditionTest.EvaluatesTrueWhenTimeExceeded
[       OK ] TimeConditionTest.EvaluatesTrueWhenTimeExceeded (0 ms)
[ RUN      ] TimeConditionTest.HandlesZeroDuration
[       OK ] TimeConditionTest.HandlesZeroDuration (0 ms)
[ RUN      ] TimeConditionTest.HandlesInvalidDuration
[TimeCondition] Invalid duration_seconds parameter: invalid_number
[       OK ] TimeConditionTest.HandlesInvalidDuration (0 ms)
[ RUN      ] TimeConditionTest.GeneratesCorrectMessage
[       OK ] TimeConditionTest.GeneratesCorrectMessage (0 ms)
[ RUN      ] TimeConditionTest.DemonstrateMockUsage
[       OK ] TimeConditionTest.DemonstrateMockUsage (0 ms)
[----------] 8 tests from TimeConditionTest (0 ms total)

[----------] Global test environment tear-down
[==========] 8 tests from 1 test suite ran. (0 ms total)
[  PASSED  ] 8 tests.
peter@Peter:~/haptech/core/tests/build$
```

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

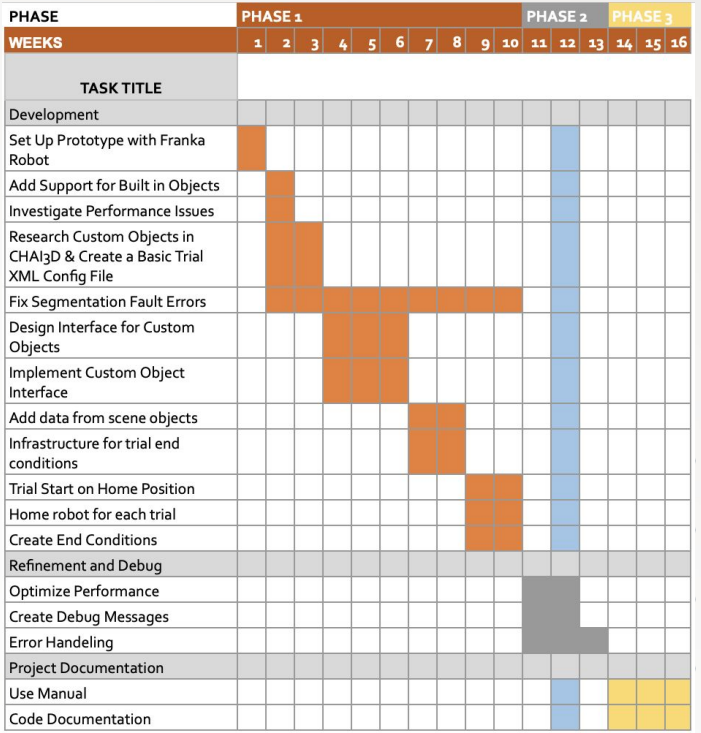
Issues: Mixed source crashing.

Solution: Added debugging, proper shutdowns, code review.

Impact: No more crashes.

Project Schedule

- Phase 1 - Main Integration
  - Core components of codebase
- Phase 2 - Polishing Steps (Current)
  - Optimization
  - Error Handling
- Phase 3 - Documentation
  - User Manual
  - Documentation in code



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:

- Final optimizations, and small additions.
- Document the project and include an user manual.
- We are confident and excited to deliver a meaningful and impactful solution that helps advance the technology of Human Robot Interaction

Thank You!

Any questions?