Accessible Federated Learning: A Student-Centered Framework

RIT

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Motivation

- This project addresses a common barrier in computational research: the steep learning curve of powerful, developer-centric tools.
- The goal was to make a complex federated learning (FL) framework accessible to student researchers new to the field.
- The original "by researchers, for researchers" design created significant accessibility challenges.

Background

- The project focused on an existing PhD research team's FL simulation framework.
- This framework is a robust Python engine with 10 aggregation strategies, 7 datasets, and Byzantine attack mitigation.
- While functionally solid, it lacked the interfaces, documentation, and test coverage needed for broad student use.

Accessibility Gap

- The core gap was the lack of an intuitive user experience, which hindered student onboarding and experimentation.
- There was no comprehensive test suite to ensure users could trust the simulation results.
- The framework was not accessible programmatically via an API or a web-based interface.

Core Project Goals

- **Trust:** Develop comprehensive pytest coverage to ensure users could trust the simulation results.
- **Accessibility:** Create intuitive interfaces and documentation targeting student researchers new to federated learning.
- **Integration:** Develop a RESTful API layer to enable programmatic or browser-based interaction.
- **Education:** Implement a thoughtful UX design to explain complex FL concepts clearly, guiding users without patronizing them.

Methodology

- **Development:** Utilized an iterative, specification-driven development approach with continuous integration.
- **Testing:**
  - Wrote comprehensive test suites concurrently with feature development.
  - Established a pytest suite with 1,136 tests, achieving over 95% coverage on critical logic.
- **Phased Approach:**
  - **Phase 1:** Built testing infrastructure (1,136 tests).
  - **Phase 2:** Developed a FastAPI RESTful API (12 endpoints).
  - **Phase 3:** Created a React 19 web frontend (50+ components).
  - **Phase 4:** Established developer tooling (Ruff, mypy, pytest-xdist)

Objectives

- Implement pytest tests (unit, integration, performance) to validate combinations of strategies, datasets, and attacks.
- Build a FastAPI backend with endpoints for simulation management, status tracking, and result retrieval.
- Design a React frontend with a configuration wizard, live dataset autocomplete, and interactive Recharts visualizations.
- Author comprehensive guides and implement extensive tooltips to explain complex FL concepts.

Results & Impact

- **For Students:**
  - Reduced onboarding time through comprehensive tooltips and validation.
  - Built confidence in results via the extensive test suite.
  - Enabled rapid experimentation with a web UI, removing the need for CLI expertise.
- **For Maintainers:**
  - The test suite prevents regressions by catching bugs early.
  - The API-first design enables future integrations like Jupyter notebooks.
  - Established code quality standards (zero linter violations) for future contributors.

Technologies

- **Backend:** Python, FastAPI, pytest, Flower.ai
- **Frontend:** React, Vite, Recharts, Material Design 3
- **Data & CI/CD:** Hugging Face Datasets, GitHub Actions

Enhancing the IntelliFL Federated Learning Framework

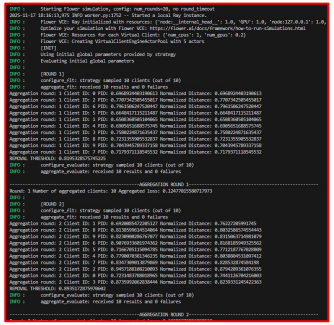
AJ Barea | Rochester Institute of Technology | Advisor: Dr. Leon Reznik

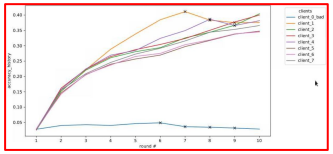
THE CHALLENGE

The IntelliFL framework was a robust Python simulation engine lacking the infrastructure for simple onboarding and reproducible research at scale.

THE TRANSFORMATION

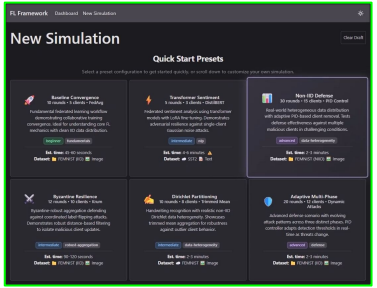
↓ BEFORE: CLI-Only ↓

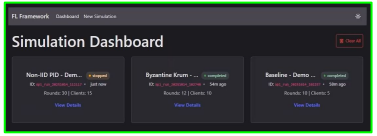


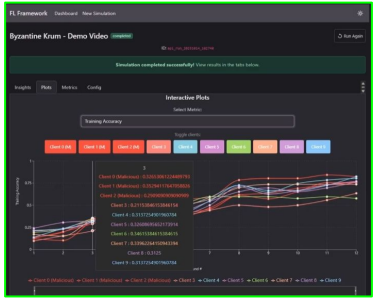


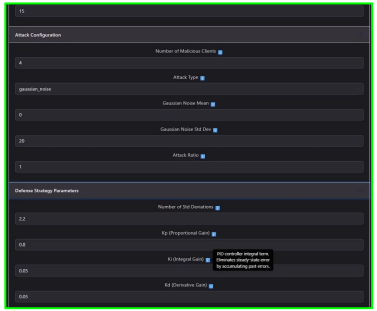
- Manual editing, no pre-validation
- Text logs only
- Static post-analysis review

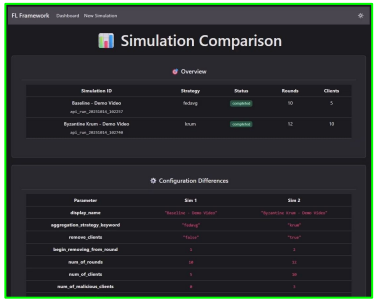
↓ AFTER: Full-Stack Infrastructure ↓

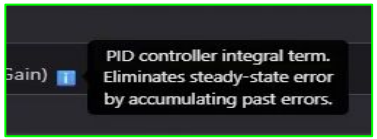


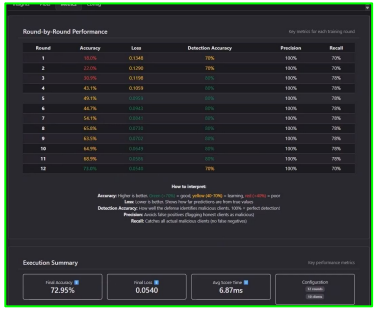












IMPACT

1,136 Tests
Comprehensive pytest suite

95% Coverage
Mission-critical code validated

12 Endpoints
RESTful API + async I/O

50+ Components
React 19 SPA with Recharts

Extensibility
API design enables cloud or automation integrations

Velocity
Reduced test runtime to under 90 seconds

Reproducibility
Ensures trustworthy simulation results

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THE CHALLENGE

The IntelliFL framework is a robust Python simulation engine with **10 aggregation strategies** and **Byzantine attack mitigation**–but it was CLI- only, lacked documentation, and had no testing infrastructure for reproducible research.

THE SOLUTION

Trust: Comprehensive pytest suite ensuring reproducible simulation results

Integration: FastAPI backend enabling programmatic & browser-based access

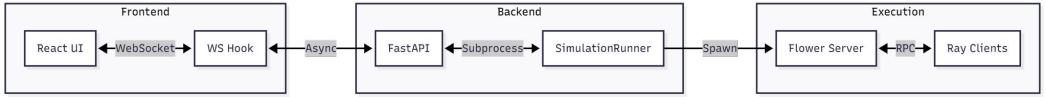
Accessibility: React 19 frontend with guided configuration wizard

Velocity: Modern DX toolchain with parallel test execution

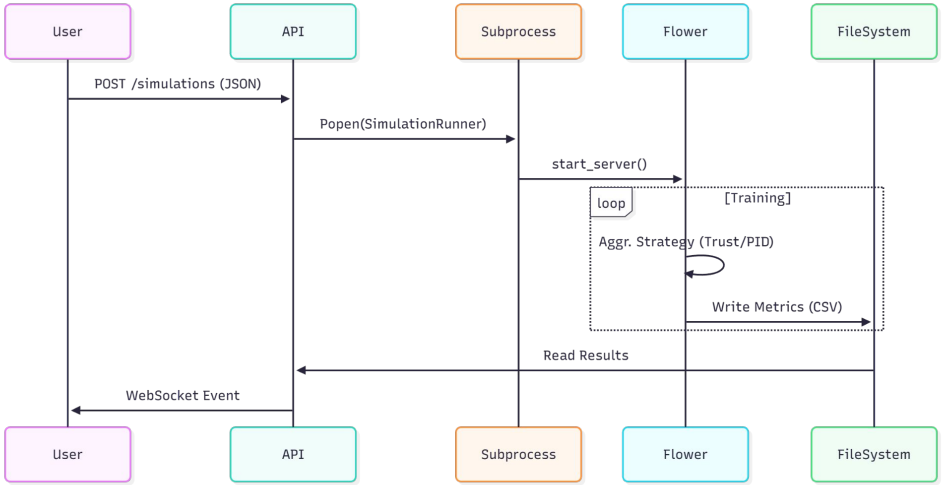
TECHNOLOGIES

Backend: Python, FastAPI, pytest, Flower ai
Frontend: React 19, Vite, Recharts
Data: Hugging Face Datasets
CI/CD: GitHub Actions, CodeCov

SYSTEM ARCHITECTURE



SIMULATION WORKFLOW



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