IFT6162 – Homework 1

This repository contains three programming assignments for **IFT6162** covering dynamic programming, optimal control, and numerical methods.

Grading and Time Allocation

Please read `GRADING_AND_TIME_ALLOCATION.md` first for: - Detailed grading rubric and point distribution - Time allocation recommendations - Submission requirements and expectations - Debugging tips and common pitfalls

Quick Overview

Problem	Weight	Time	Files
Supermarket Refrigeration (Trajectory Optimization MPC)	45%	12-15h	`supermarket_refrigeration/`
Bus Engine Replacement (Smooth Bellman & NFXP)	35%	8-10h	`bus_engine_replacement/`
Projection Methods (Collocation & Galerkin)	20%	5-7h	`projection_methods_assignment/`

Total estimated time: 25-32 hours

Quick Start

Environment Setup

Create a virtual environment at the project root:

```
python3 -m venv venv
source venv/bin/activate
pip install --upgrade pip
pip install numpy scipy matplotlib jax jaxlib jaxopt optax chex absl-py
```

Running the Assignments

Each problem has detailed instructions in its respective `question.md` file:

1. **Supermarket Refrigeration:**

```
cd supermarket_refrigeration
python3 trajectory_optimization.py          # Quick test (30 min)
python3 trajectory_optimization.py --full   # Full evaluation (4 hours)
```

2. **Bus Engine Replacement:**

```
cd bus_engine_replacement
python3 bus_replacement.py                  # Runs in 2-3 minutes
```

3. **Projection Methods:**

```
cd projection_methods_assignment
python3 timber_projection.py                # Test implementations
python3 contraction_investigation.py        # Verify contraction properties
```

Submission Requirements

You are NOT required to write formal multi-page reports. For each problem:

- Submit your completed implementation files
- Include generated plots and output metrics
- For Problem 1 only: Add brief commentary (1-2 paragraphs) on results
- No lengthy derivations or literature reviews needed

Problem Descriptions

Problem 1: Supermarket Refrigeration (45%)

Implement multiple shooting Model Predictive Control for a hybrid refrigeration system. You'll coordinate compressors and valves to minimize energy while respecting temperature and pressure constraints. Uses JAX for autodiff and SLSQP for constrained optimization.

Problem 2: Bus Engine Replacement (35%)

Implement Harold Zurcher's bus engine replacement model using smooth Bellman equations. Estimate cost parameters via maximum likelihood with the NFXP algorithm and implicit differentiation through fixed-point solvers.

Problem 3: Projection Methods (20%)

Implement collocation and Galerkin methods for continuous-state dynamic programming. Solve a timber harvesting problem and investigate when parametric value iteration converges.

Debugging Tips

- **JAX issues:** Use `jnp` instead of `np` inside JIT-compiled functions

- **Constraint violations:** Check that temperature and pressure bounds are being satisfied
- **Slow convergence:** Verify warm-starting and check that gradients are being computed correctly
- **Numerical instability:** Use log-space operations (logsumexp) for probabilities

Additional Resources

Each subdirectory contains: - `question.md`: Detailed problem description and mathematical background - Template files with `TODO` markers indicating what to implement - Helper functions and simulation code (already implemented)

See `GRADING_AND_TIME_ALLOCATION.md` for comprehensive guidance on each problem.