COM 407 Project Proposal

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Title: Imitation Learning from Specialized Agents for Enhanced XPilot AI Performance

1. Overview

This project aims to design and evaluate an imitation learning system in the XPilot game environment, focusing on whether training on demonstrations from multiple specialized agents can produce a more capable and adaptive AI agent than training on a single expert. XPilot provides a rich and dynamic 2D combat environment, making it an ideal testbed for learning control, navigation, and decision-making in real time.

While much previous work on XPilot has focused on reinforcement learning (e.g. Q-Learning and DQN-based agents), this project will explore imitation learning, training a neural network to imitate expert player behaviors through supervised learning. The research question is whether combining demonstrations from different specialized agents (for instance, an agent good at dodging, another good at aiming, and another good at collecting power-ups) can lead to a single, hybrid agent that performs more effectively than any of the original experts individually. The aim of this project is not to make a better bot but to see if imitating several good bots creates a best one.

2. Background and Motivation

Previous studies (e.g., Martin Allen's "XPilot AI Reinforcement Learning" paper, 2010) have shown that reinforcement learning in XPilot is often limited by the engine's data collection constraints and the immense number of episodes needed for convergence. In contrast, imitation learning is far more data-efficient, allowing for faster convergence using recorded human or AI expert data.

However, imitation learning from a single expert may result in overfitting to that expert's playstyle. Drawing inspiration from DeepMind's AlphaStar, which used multi-agent training to achieve diverse strategies, this project investigates whether integrating demonstrations from multiple specialists can lead to more robust and generalized gameplay strategies within XPilot's complex environment.

3. Project Goals

1. Collect demonstration data from several specialized XPilot agents, each exhibiting a distinct skill or behavior (e.g. offense, defense).

2. Train separate imitation learning models on each dataset to understand specialization performance.

3. Combine and integrate the trained models or datasets to train a unified neural network that aims to generalize across behaviors.

4. **Evaluate performance** using various metrics (win rate, survival time, score) and qualitative behavioral comparison to the training experts.

4. Methodology

- **Data Collection:**
    - Record game state transitions (e.g. position, velocity, angle) from multiple specialized agents.
    - Store data as structured state action pairs for supervised learning.
- **Model Architecture:**
    - Use a neural network (probably using PyTorch), consisting of input layers for structured state representation, hidden layers (probably with RELU activation), and output layers predicting optimal actions.
    - Compare models trained on single-agent data vs. multi-agent combined data.
- **Training:**
    - Supervised learning using mean squared error (MSE) loss between predicted and expert actions.
    - Evaluate training convergence using validation loss and in-game performance.
- **Evaluation Metrics:**
    - Average score, time survived
    - Behavioral analysis to see whether hybrid agents exhibit balanced strategies.

5. Expected Outcomes

- A trained imitation learning model capable of playing XPilot competently using data from multiple experts.

- Insight into whether diverse training sources improve generalization and performance compared to single-expert imitation.

- A framework that could later be extended to combine imitation and reinforcement learning, forming a foundation for more advanced hybrid models.