Project Proposal

Simulating Kite Surfing: From Real-World Data to a Virtual Training Environment for RL Agents

---

General Information

Type:	Semester Project (10 ECTS) or Master Thesis (30 ECTS)
Laboratory:	Laboratory for Applied Mechanical Design (LAMD)
Supervisors:	A. Artomov; H. Jubran; Prof. J. Schiffmann
Location:	Neuchâtel[1] (travel expenses are covered by the lab)
Contacts:	andrii.artomov@epfl.ch; husam.jubran@epfl.ch
Website:	https://www.epfl.ch/labs/lamd/

Background

Kite surfing is a complex sport requiring precise control of the kite, board, and body position to achieve optimal performance in dynamic wind and water conditions. A project partner has collected extensive sensor data from kite surfers to better understand the underlying physics of the sport. This project leverages this data to build mathematical models, create a virtual simulation environment, and explore the potential of reinforcement learning to identify optimal kite surfing strategies. Through this project, students will gain practical experience in data analysis, physics-based modeling, virtual environment creation, and reinforcement learning techniques, all while tackling real-world challenges. The project provides flexibility in tools, allowing students to select a preferred platform for the simulation environment (e.g., Unity, Unreal Engine, MuJoCo, PyBullet, Blender + Python, Simulink etc.).

Objective

The objective of this project is to bridge the gap between real-world data and virtual simulation by developing a comprehensive understanding of kite surfing dynamics and creating a realistic virtual training environment. Using sensor data collected from actual kite surfers, the project will focus on building data-driven and physics-based models to explain and predict the interactions between the surfer, kite, wind, and water. A key outcome is the creation of a flexible simulation environment to replicate kite surfing under various conditions. In this environment, reinforcement learning agents will be trained to identify efficient kite surfing strategies, enabling the observation of intelligent behavior and providing valuable insights into effective techniques and approaches. This work serves as a foundational step toward deeper exploration of kite surfing dynamics and applications of AI in sports training.

Tasks

Below is the structured list of tasks to guide the project:

1. **Literature Review**
   - Investigate previous research on:
     - Kite surfing dynamics and modeling.
     - Physics-based simulation techniques.
     - Reinforcement learning applications in dynamic systems.
   - Review tools available for simulation and modeling, such as Unity, Unreal Engine, MuJoCo, PyBullet, Blender, and Simulink.

[1] The possibility to work from the EPFL main campus in Lausanne can be discussed

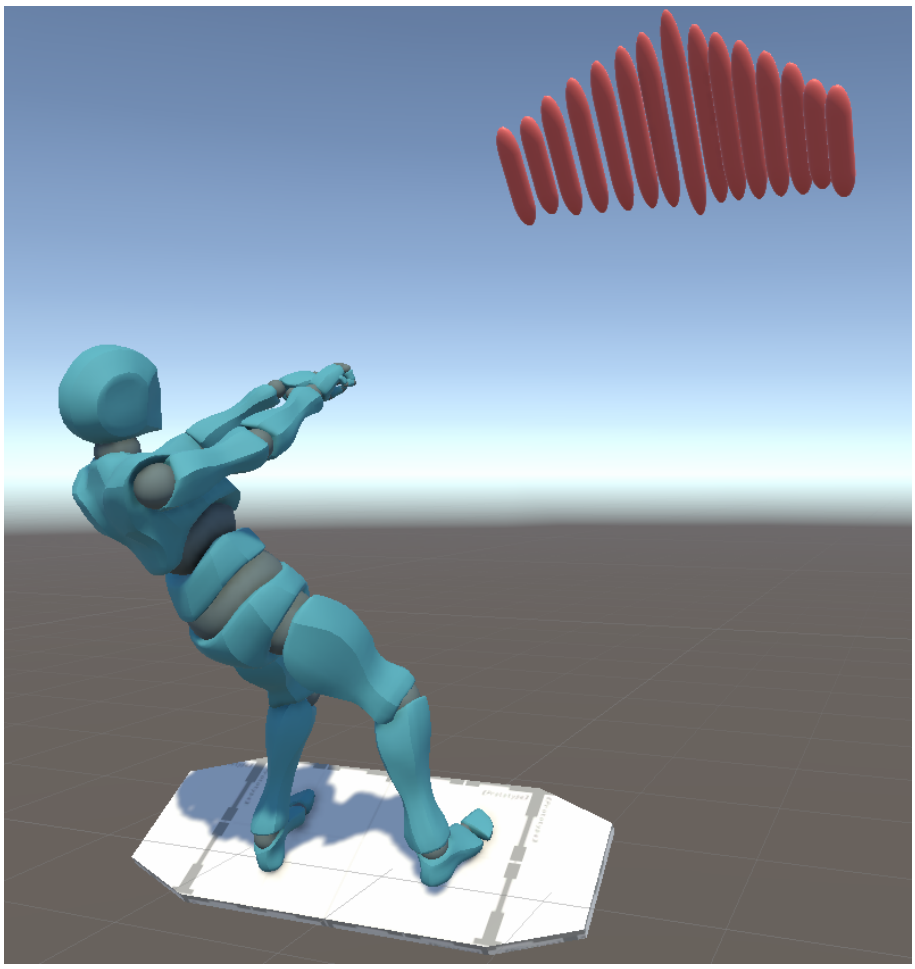

Figure 1: Potential environment setup (created with Unity)

2. **Data Analysis**
   - Examine the dataset provided by the industrial partner:
     - Preprocess and clean the sensor data.
     - Perform exploratory data analysis to identify key variables (e.g., wind speed, kite angle, surfer velocity).
     - Identify patterns, relationships, and anomalies in the data.
   - Generate visualizations to communicate findings.
3. **Model Creation**
   - Develop mathematical or machine learning models to explain the dynamics of kite surfing.
     - Use sensor data to create physics-based equations or data-driven models.
     - Validate models against the provided data.
   - Analyze the sensitivity of the models to key parameters.
4. **Environment Setup**
   - Select the most suitable tool for creating the virtual environment:
     - Evaluate the listed tools (Unity, Unreal Engine, MuJoCo, PyBullet, Blender + Python, Simulink) based on project requirements such as:
       * Physics simulation accuracy.
       * Ease of integrating reinforcement learning frameworks.
       * Visualization quality and interactivity.
       * Learning curve and time constraints.

  - Justify the choice of tool with a comparison of strengths and limitations.
- Create the virtual environment using the selected tool:
  - Define and integrate environmental variables (e.g., wind, water resistance).
  - Simulate surfer dynamics based on the developed models.
  - Incorporate realistic visualization of the kite surfing environment.

5. **Reinforcement Learning Exploration (Master thesis only)**
   - Design and implement a reinforcement learning framework:
     - Define a reward function aligned with performance objectives (e.g., speed, distance, stability).
     - Train RL agents to optimize surfer behavior in the virtual environment.
   - Evaluate the performance of the RL agent and compare it with human performance.
6. **Reporting and Presentation**
   - Document the methodology, results, and insights gained during the project.
   - Present findings.

NB: adjustments may be required according to progress, results, and project duration.

Prerequisite knowledge

Python and/or Matlab