Greenhouses of the Future

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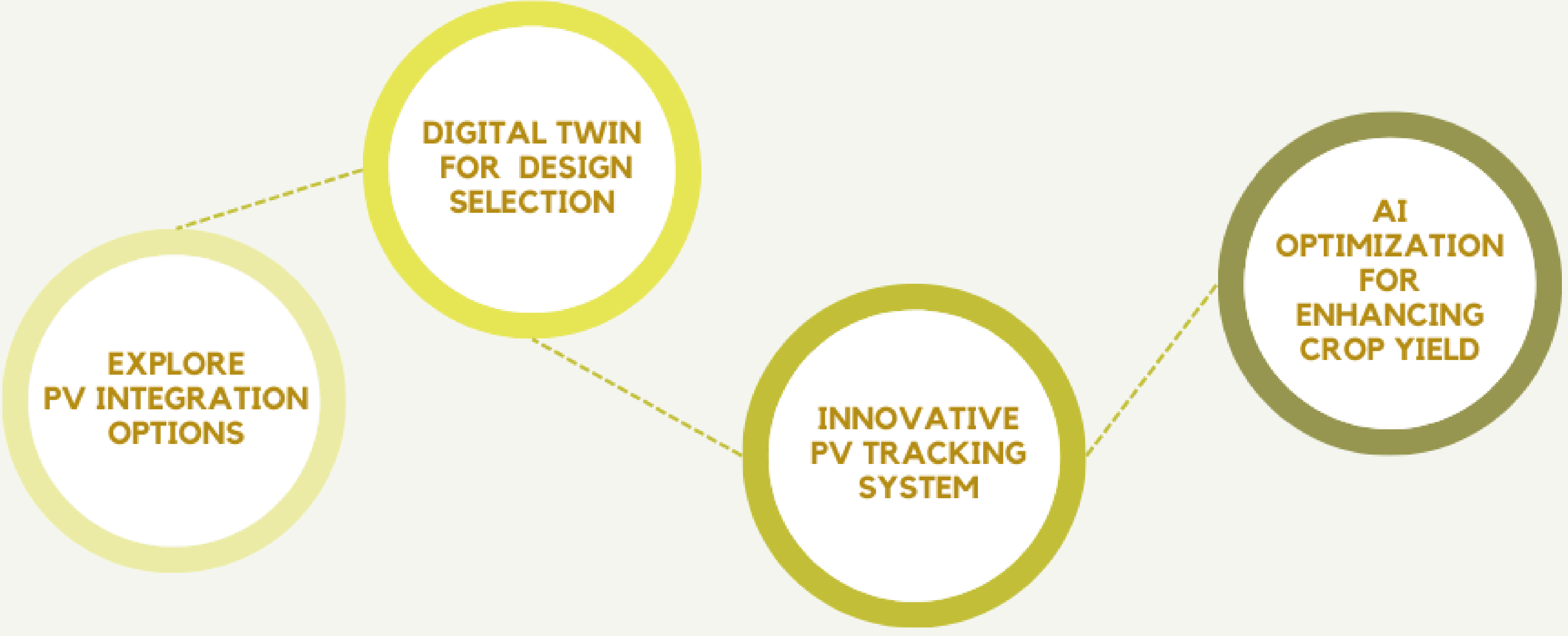
INTRODUCTION

This project aims to model a greenhouse, creating an AI-integrated Digital Twin (DT) design for holistic energy management. It strives to develop a smart, sustainable system using sensor and IoT data to optimize energy usage, including integrated solar PV systems. This inclusive approach considers plant growth constraints and involves greenhouse owners in decision-making.

OBJECTIVE

- Develop a holistic Digital Twin (DT) design for greenhouse horticulture energy management and operation.
- Explore and evaluate various design options for integrating solar panels into greenhouse structures to optimize energy generation and plant growth.
- Implement an AI monitoring system that utilizes data from sensors and IoT devices for real-time optimization of greenhouse conditions, by adjusting factors like sunlight exposure with flexible PV tracks.

METHODOLOGY



EXPLORE PV INTEGRATION OPTIONS

DIGITAL TWIN FOR DESIGN SELECTION

INNOVATIVE PV TRACKING SYSTEM

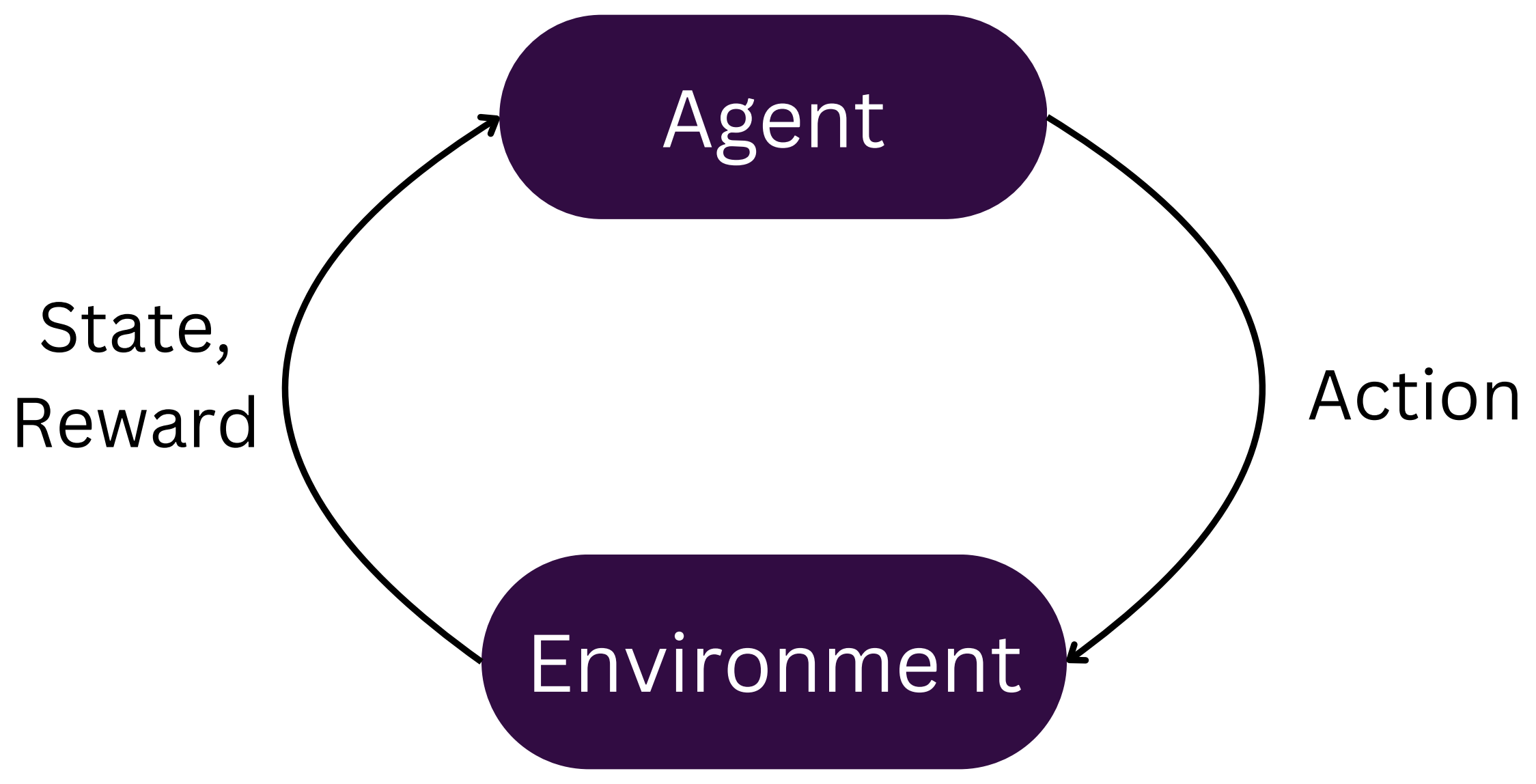
AI OPTIMIZATION FOR ENHANCING CROP YIELD

SCENARIO ANALYSIS: LETTUCE SIMULATION

Objective: Evaluate reinforcement learning algorithms' efficacy in greenhouse parameter control under variable weather conditions for optimal sustainable operation.
Initial exploration: Modeling various AI sub-models using reinforcement algorithms for lettuce cultivation in a greenhouse.

- Reinforcement Learning (RL): Trains agents to make decisions by interacting with the environment.
- Advanced RL models explored, included Proximal Policy Optimization (PPO), Soft Actor-Critic (SAC), Deep Deterministic Policy Gradient (DDPG), and Twin Delayed Deep Deterministic Policy Gradient (TD3).
- Models were trained on variable weather scenarios to assess greenhouse parameter control (incl. uncertainties called *Noise*).
- Environment allows agents to manipulate inputs such as CO2 supply rate, heating power, and ventilation.

Figure 1: In RL, agents receive rewards from the environment indicating the state's performance. Rewards can be positive or negative based on actions.



RESULTS

- In February (*Fig. 2a and b*), TD3 and PPO achieve the best mean reward but yield similar lettuce amounts to agents trained with noise, while DDPG performs poorly without noise.
- In June *(Fig. 2c and d)*, plant deaths occur due to temperatures exceeding 40°C. DDPG and TD3 survive with weather variation and noise, while SAC thrives without noise, and dry weight remains consistent among surviving agents.
- Across scenarios: PPO consistently excelled and rapidly reached its peak. TD3 demonstrated efficiency, needing fewer attempts, while both TD3 and DDPG displayed adaptability to varying greenhouse conditions.

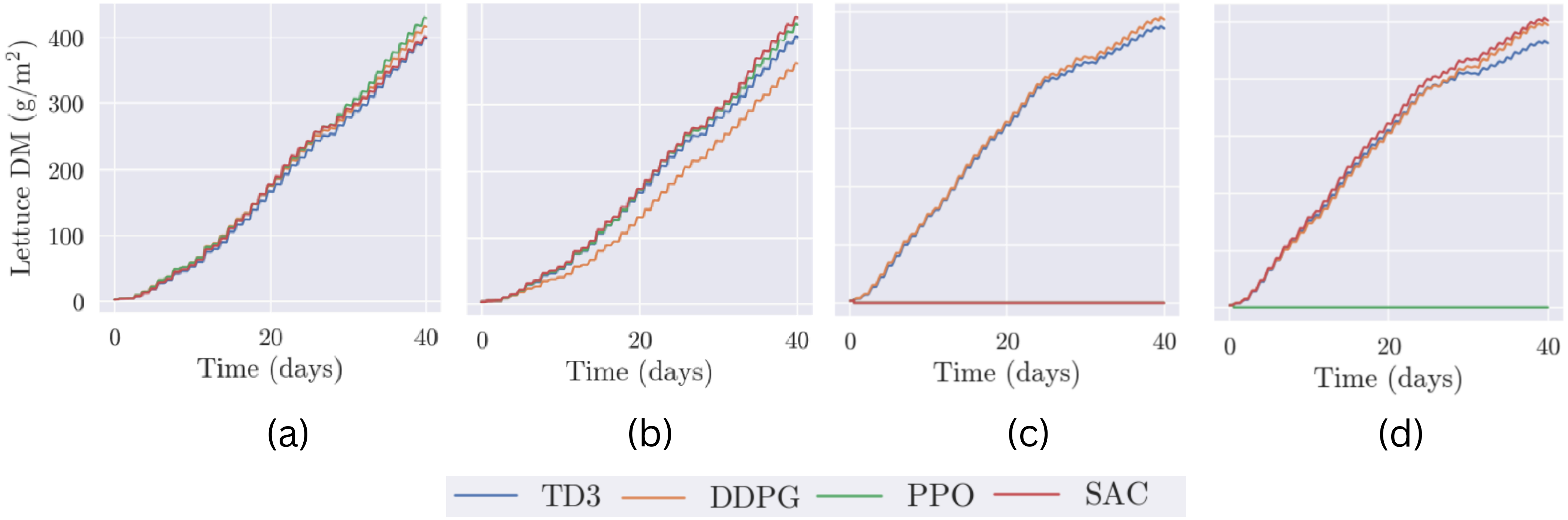


Figure 2: (a) Noise, February (b) No Noise, February (c) Noise, June (d) No Noise, June

CONCLUSION

This project highlights the potential of integrating solar panels, AI monitoring systems, and Digital Twin designs into greenhouse agriculture to create sustainable environments. By leveraging advanced technologies, we aim to optimize energy management, crop yield, and overall efficiency. We plan to implement various designs, both PV-integrated and independent greenhouses, to achieve these objectives.

REFERENCES
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