Milestone 1 - Project Proposal
CS 4632 WO1 Modeling and Simulation
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Comprehensive Report: Efficient ADU Design Simulation

1. Model Selection

System Description: The system to be modeled is the design and placement of **Accessory Dwelling Units (ADUs)** on existing residential properties. ADUs are small, self-contained housing units that can provide additional living spaces while addressing urban housing challenges such as affordability, density, and sustainability.

Model Type: A **discrete-event simulation** (DES) model will be used to represent the sequential processes of designing, placing, and evaluating ADUs under various constraints. Additionally, elements of **continuous modeling** will be employed to simulate energy efficiency and sunlight exposure over time.

Key Components:

- **Property Constraints:** Dimensions, slope, and zoning regulations.
- **ADU Design Variables:** Floor plan layout, material choices, and energy systems.
- **Performance Metrics:** Construction cost, energy efficiency, and usable living space.
- **External Factors:** Sunlight exposure, climate conditions, and utility connections.

Reason for Selection: This model allows for a systematic exploration of ADU designs and their performance across a range of real-world scenarios. The discrete-event approach captures step-by-step processes like construction planning and cost estimation, while the continuous component analyzes long-term efficiency metrics like energy use.

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2. Implementation Approach

Tools and Frameworks:

- **Programming Language:** Python, for its flexibility and libraries like SimPy (for DES) and Matplotlib (for visualization).
- **Energy Modeling Tools:** OpenStudio or EnergyPlus for analyzing energy efficiency.
- **GIS Software:** QGIS, to incorporate geospatial data like property dimensions and sunlight exposure.
- **Version Control:** GitHub, for managing project code and collaboration.

Implementation Steps:

1. **Phase 1: Environment Setup and Initial Model Design**
   - Configure the development environment with Python and required libraries.
   - Collect baseline property data (e.g., dimensions, slope).
   - Develop a UML diagram to define system components and their interactions.
2. **Phase 2: Core Model Development**
   - Implement discrete-event simulation logic to evaluate design scenarios.
   - Integrate energy modeling to assess efficiency metrics like insulation performance and solar gain.
   - Automate data collection for construction cost, energy usage, and livable space.
3. **Phase 3: Advanced Features and Testing**
   - Add real-time visualization of simulation outcomes (e.g., graphs and charts).
   - Implement an optimization algorithm to suggest the best ADU configuration for a given property.
   - Conduct validation using real-world data from existing ADU designs.
4. **Phase 4: Documentation and Final Refinement**
   - Document the system architecture, assumptions, and limitations.
   - Perform sensitivity analysis to understand the impact of key variables.
   - Finalize the simulation and prepare it for presentation.

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3. Planned Simulation Methodology

Purpose: To simulate and optimize ADU designs for existing properties, considering constraints such as property size, slope, and energy efficiency, while maximizing livable space and minimizing costs.

Simulation Scenarios:

1. **Baseline Scenario:**
   - Flat, rectangular property with no significant constraints.
   - Standard ADU design and placement.
2. **Edge Cases:**
   - Properties with steep slopes or irregular shapes.
   - Limited utility connections or zoning restrictions.
3. **Validation Scenario:**
   - Simulated designs compared to performance metrics from real-world ADUs.

Data Collection and Analysis:

- **Data Points:** Construction cost, energy consumption, sunlight exposure, and livable space.
- **Storage Format:** CSV for numerical data, JSON for simulation configurations.
- **Analysis Tools:** Python libraries for statistical analysis and visualization.

Validation Strategy:

- Verify simulation accuracy by comparing outputs to theoretical predictions and real-world data.
- Perform sensitivity analysis to evaluate the robustness of the model.
- Use peer-reviewed research on ADU design and energy efficiency for additional validation.

Expected Outcomes:

- Identification of optimal ADU designs under various constraints.
- Insights into the trade-offs between construction cost, energy efficiency, and livable space.
- A framework for property owners and developers to evaluate ADU feasibility and performance.

4. Enhanced Criteria for Rubric Alignment

Problem Definition: This project addresses the challenge of optimizing ADU designs on existing properties by simulating design variables and external constraints. The goal is to balance energy efficiency, construction cost, and livable space while adhering to zoning regulations.

System Context: The simulation interacts with external factors such as zoning laws, property layouts, climate data, and utility connections. Dependencies include material cost databases and geographic information for sunlight exposure analysis.

Mathematical Model: Key equations include:

- **Heat Loss:** $Q = \text{U-value} * \text{Area} * \Delta T$ (energy efficiency metric).
- **Construction Cost:** Cost = Material_cost * Quantity + Labor_cost.
- **Space Utilization:** Usable_area = Total_area - Non-livable_space.

Variables are defined for property dimensions, slope angles, solar exposure indices, and material costs.

Literature Review: References include studies on energy-efficient housing design, discrete-event simulation methodologies, and tools like OpenStudio and SimPy. Case studies of existing ADU implementations are cited to validate assumptions.

Component Architecture: The system includes:

1. **Property Model:** Represents physical constraints.
2. **ADU Design Module:** Handles floor plans and material selection.
3. **Simulation Engine:** Executes design scenarios.
4. **Data Analysis Module:** Collects and visualizes results.

System Behavior: Triggers include adjustments in property slope or material choices, leading to recalculations of feasibility metrics. State changes occur as designs are iterated upon based on performance outcomes.

Implementation Planning:

- **Timeline:**
  - Week 1-2: Research and environment setup.
  - Week 3-4: Core simulation development.
  - Week 5-6: Data collection and validation.
  - Week 7-8: Final refinement and presentation.
- **Resources:** Python, SimPy, OpenStudio, and GitHub.
- **Risks:** Data inaccuracies and tool integration challenges.

Validation Strategy: Metrics include energy efficiency (heat loss), construction cost, and space utilization. Success criteria involve alignment with theoretical models and real-world ADU data. Sensitivity analysis ensures robustness.

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5. Preliminary Implementation Timeline and Resource Requirements

Timeline:

1. **Week 1-2:**
   - Research foundational ADU design principles and collect property data.
   - Set up the development environment and required libraries/tools.
   - Draft UML diagrams for the system architecture.
2. **Week 3-4:**
   - Develop the core simulation logic using Python and SimPy.
   - Implement basic energy modeling using OpenStudio.
   - Create initial automation scripts for data collection and analysis.
3. **Week 5-6:**
   - Conduct data validation and refine the simulation model.
   - Add advanced features, such as optimization algorithms for design recommendations.
   - Begin testing and debugging.
4. **Week 7-8:**
   - Finalize simulation features and conduct sensitivity analysis.
   - Prepare final documentation and presentation materials.

Resource Requirements:

- **Hardware:** Standard computer with Python-compatible specifications.
- **Software:**
  - Python (with libraries like SimPy, Matplotlib, Pandas).
  - OpenStudio/EnergyPlus for energy modeling.
  - QGIS for geospatial data integration.
  - GitHub for version control and collaboration.
- **Data Sources:** Property dimensions, slope data, and energy cost metrics.
- **Team Resources:** Access to peer-reviewed research and relevant ADU design studies.

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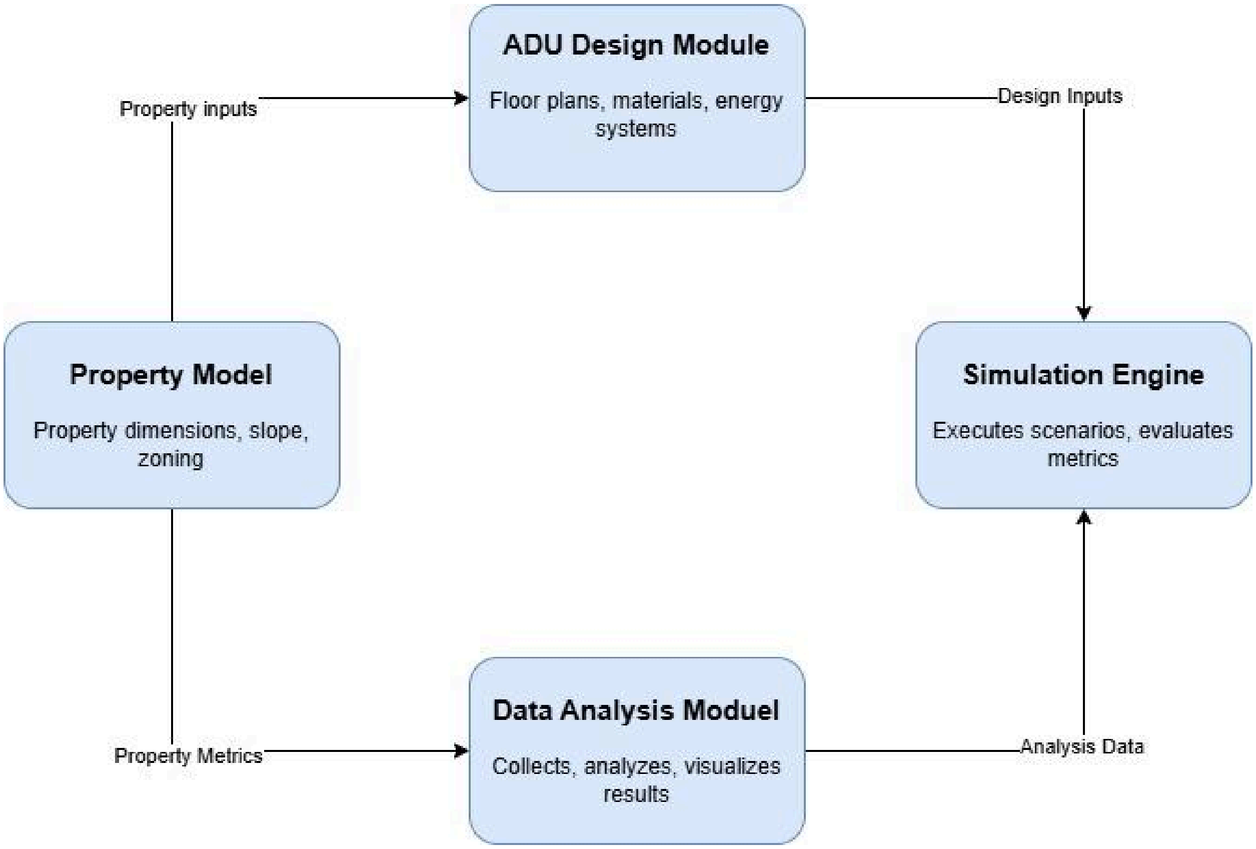
6. Risk Assessment and Mitigation Strategies

Identified Risks:

1. **Data Inaccuracies:**
   - Risk: Collected property data or material costs may be incomplete or outdated.
   - Mitigation: Cross-verify with multiple sources and use updated datasets whenever possible.
2. **Integration Challenges:**
   - Risk: Difficulty in integrating tools like OpenStudio with Python-based simulations.
   - Mitigation: Allocate additional time in Phase 2 for integration testing and seek support from tool documentation or online forums.
3. **Simulation Complexity:**
   - Risk: Overly complex models could lead to excessive runtime or errors.
   - Mitigation: Begin with simplified models and incrementally add complexity. Regularly benchmark performance.
4. **Timeline Delays:**
   - Risk: Unexpected challenges might extend the project timeline.
   - Mitigation: Build buffer time into each phase and prioritize critical tasks.
5. **Validation Issues:**
   - Risk: Simulated results may not align with real-world ADU performance data.
   - Mitigation: Use sensitivity analysis to identify discrepancies and adjust model assumptions.

By addressing these risks proactively, the project ensures smoother implementation and robust outcomes.


ADU Design Module
Floor plans, materials, energy systems
Property inputs
Design Inputs
Property Model
Property dimensions, slope, zoning
Simulation Engine
Executes scenarios, evaluates metrics
Property Metrics
Analysis Data
Data Analysis Moduel
Collects, analyzes, visualizes results