American International University Bangladesh

FACULTY OF SCIENCE and TECHNOLOGY

Computer Graphics

Project Report

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Group – G

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Title: Solar-Powered City Simulation during Load shedding.

List of Group Members: Group G

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Introduction:

Cities are rapidly evolving ecosystems that combine infrastructure, technology, and human activity. With the growth of industrialization and urbanization, modern cities face a pressing set of challenges: rising energy consumption, climate change, frequent blackouts, and sustainability concerns. Among these, the reliance on fossil fuels and conventional energy grids has created vulnerabilities that threaten both quality of life and long-term development. Addressing these issues requires innovative solutions that blend renewable energy, efficient infrastructure design, and awareness of modern technologies.

In this context, computer graphics-based simulation projects offer a unique opportunity to visualize and model smart energy systems for urban environments. The present project—*Solar-Powered City Simulation*—is developed using OpenGL in C++. It simulates a small but dynamic cityscape that demonstrates the importance of renewable energy integration, blackout resilience, and sustainable urban planning. Through the simulation, users can experience both day and night cycles, vehicles on the road with functional headlights, airplanes passing overhead, moving clouds, colorful buildings, and most importantly, the role of solar panels in maintaining city functions during energy blackouts.

Motivation of the Project

Energy crises and climate change are no longer distant threats—they are ongoing realities. Bangladesh, like many other developing nations, faces frequent power outages and rising energy demand. Globally, electricity consumption increased by 1 080 TWh, nearly two times the annual average of the past decade [4]. These problems raise critical questions:

- How can cities reduce dependency on centralized power grids?
- What role can renewable sources like solar energy play?
- How can ordinary citizens understand and visualize the importance of such systems?

Our project attempts to address these questions by creating a visual demonstration where solar panels sustain critical infrastructure even during blackouts. This is not only an educational tool but also a step toward raising awareness of green technologies through interactive computer graphics.

Role of Computer Graphics in Urban Sustainability

Simulations are powerful because they enable people to see complex systems in action. While mathematical models and statistics explain renewable energy's impact, a visual model makes it tangible. OpenGL, a widely used graphics library, allows us to recreate lifelike scenes—moving vehicles, glowing lights, changing skies—that mirror real-world scenarios. By embedding sustainability concepts into these visualizations, we combine technology with education.
This approach has two key benefits:

1. **Education and Awareness**: Students and citizens can learn how solar panels work, why blackout resilience is critical, and how city infrastructure interacts with energy systems.
2. **Prototyping and Planning**: City planners and engineers could use simulations to predict challenges in implementing renewable systems and test design solutions virtually before real-world deployment.

Overview of the Simulation Features:

The simulation represents a small urban setting with essential components:

- **Day and Night Cycle**: The sun moves across the sky during the day, while the moon replaces it at night. This reflects natural time progression.
- **Cloud Movement**: Clouds drift across the sky, symbolizing dynamic atmospheric conditions.

- **Vehicles and Roads**: Cars move along a two-lane road with headlights that activate at night, demonstrating energy use in transportation.
- **Airplane Animation**: An airplane occasionally enters the scene, adding realism and emphasizing air travel as part of modern urban life.
- **Railway and Train**: A railway line with a moving train adds another layer of transportation infrastructure. The animated train highlights the importance of **public transport** in reducing congestion and promoting
- **Buildings with Solar Panels**: Colourful buildings light up at night. When solar panels are installed, they continue to function even during blackout simulations, highlighting resilience.
- **Streetlights and Blackouts**: Roadside lights glow at night but turn off during a blackout, unless solar energy is enabled. This contrast educates users on the difference between grid dependency and renewable self-sufficiency.

Through these features, the simulation acts as a miniature smart city prototype that demonstrates how renewable energy can power essential infrastructure.

Importance of Solar Power in Cities

Solar energy is among the most accessible renewable resources. Unlike wind or hydroelectric systems, solar panels can be installed on almost any building rooftop, making them ideal for dense urban environments. The benefits include:

- **Energy Independence**: Solar reduces dependency on national grids.
- **Sustainability**: It produces no greenhouse gases during operation.
- **Cost Savings**: Long-term electricity costs decrease with solar adoption.
- **Blackout Resilience**: During grid failure, solar-powered buildings remain lit, ensuring safety and functionality.

In our simulation, this last aspect is particularly emphasized. By pressing a key, the user can toggle a blackout. Without solar panels, the city plunges into darkness; with solar panels activated, buildings remain powered, showing the life-saving role of renewable systems.

Broader Implications of the Project

Beyond a classroom exercise, this project has broader implications. With slight modifications, the simulation could evolve into a serious educational tool for schools and universities, raising awareness about sustainability. Policymakers could also use such visualizations to demonstrate renewable energy policies to the public in an engaging manner. Furthermore, this model could inspire game-based learning environments where sustainability concepts are taught interactively.

The project also demonstrates the value of interdisciplinary collaboration. While rooted in computer science and graphics programming, it directly connects to energy engineering, environmental science, and urban planning. By bridging these fields, the project shows how technology can advance social and environmental goals.

Structure of the Report

This report is organized into the following sections:

1. Introduction – Provides context, motivation, and scope of the project.
2. Background of the Problem – Explores the real-world issues of energy crises, blackouts, and renewable adoption.
3. Methods Used – Details the programming techniques, tools, and algorithms used in the simulation.
4. Feature Set – Explains each feature of the project in depth.

5. Future Directions – Suggests possible extensions of the simulation into more advanced smart city prototypes.
6. Conclusion – Summarizes outcomes and key lessons learned.
7. Implementation Code – Provides the complete source code for reproducibility.
8. References – Lists academic and technical sources that informed the project.

Background of the Problem:

The 21st century has been marked by unprecedented growth in cities worldwide. As people migrate to urban areas for better opportunities, urbanization has placed immense strain on infrastructure, resources, and energy systems. According to the United Nations, over 55% of the global population currently resides in urban regions, and this percentage is projected to rise to 68% by 2050 [1]. While this growth has fueled economic activity, it has also magnified the challenges of energy consumption, environmental degradation, and resilience during crises.

At the center of these challenges lies the problem of energy dependency and blackouts. Cities today are powered by vast, centralized grids that often rely on non-renewable energy sources such as coal, oil, and natural gas. These grids are vulnerable to disruptions caused by both technical faults and external stressors like climate change, extreme weather, or overconsumption. When such disruptions occur, the result is a blackout—a sudden and widespread loss of power that halts essential services, disrupts daily life, and exposes critical vulnerabilities in modern urban living.

Energy Consumption in Cities

Urban areas are responsible for a disproportionate share of global energy consumption. Skyscrapers, factories, shopping centers, hospitals, and transportation systems all depend on electricity for operation. Buildings alone consume around 40% of total energy worldwide. As cities grow larger and denser, their demand for electricity rises correspondingly. For example, the energy footprint of a modern metropolitan city is many times larger than that of rural regions, owing to its reliance on artificial lighting, climate control (heating and cooling systems), and digital infrastructure.

The heavy dependence on electricity also creates a cycle of unsustainable consumption. To meet urban demand, power plants often burn fossil fuels, releasing greenhouse gases into the atmosphere. This accelerates climate change, which in turn increases the frequency of extreme weather events, further stressing energy infrastructure. The result is a vicious cycle: cities consume energy unsustainably, and the resulting climate impacts threaten the very systems cities rely upon.

Blackouts: Causes and Consequences

Blackouts are one of the most immediate and visible consequences of energy vulnerability. They occur when the electricity supply fails to meet demand or when infrastructure malfunctions. The causes of blackouts include:

- **Overloading of grids** during peak hours, when too many users draw electricity simultaneously.
- **Natural disasters**, such as cyclones, floods, or heatwaves, which damage power lines and substations.
- **Aging infrastructure**, where outdated systems cannot handle modern loads.

The consequences of blackouts are severe:

- **Public Safety Risks**: Streetlights fail, creating unsafe conditions for pedestrians and vehicles. Hospitals and emergency services are jeopardized if backup generators fail.
- **Economic Losses**: Businesses shut down, production halts, and financial markets can be disrupted.

- **Social Disruption**: Families are left without cooling, heating, or internet services. Students cannot study, and workers cannot function efficiently.

Bangladesh, like many developing nations, has frequently experienced rolling blackouts due to high demand and insufficient generation capacity. In Dhaka, for example, entire neighborhoods have historically been left in darkness for hours, underscoring the urgency of exploring alternative, reliable, and renewable energy solutions.

Renewable Energy as a Solution

Renewable energy sources such as solar, wind, hydro, and geothermal provide a path to sustainable and resilient urban power systems. Among these, solar energy stands out because it is abundant, decentralized, and relatively easy to deploy. Every city rooftop has the potential to serve as a small power plant when equipped with solar panels. Unlike fossil fuels, solar panels generate electricity without polluting the environment.

The most significant advantage of solar power in the urban context is resilience during blackouts. A building equipped with solar panels and energy storage systems (like batteries) can continue functioning even when the central grid collapses. This capability ensures that essential services such as hospitals, schools, and public safety infrastructure remain operational. Governments worldwide have recognized this potential. Many nations now provide subsidies, tax incentives, and infrastructure support to encourage rooftop solar adoption. In Bangladesh, the Solar Home System (SHS) program has already installed millions of solar panels in rural areas, proving that even communities with limited infrastructure can harness renewable energy effectively [5].

Technology Awareness and Visualization Challenges

While renewable energy is promising, its adoption is not just a matter of technology, it is also a matter of awareness and understanding. Ordinary citizens often struggle to grasp how solar systems work, what benefits they provide, and why they should invest in them. Similarly, policymakers may find it difficult to communicate the advantages of renewable energy in a way that resonates with the public.
This is where visualization and simulation tools play an important role. By creating interactive models that demonstrate how cities function with and without renewable systems, it becomes easier to show the before-and-after impact of solar power adoption. For example:

- A city simulation where buildings go dark during a blackout clearly conveys the risks of energy dependency.

- A contrasting simulation where solar-equipped buildings remain lit demonstrates the reliability of renewable systems.

Through visual learning, concepts that may seem abstract in textbooks become concrete and memorable. This is why our project uses **OpenGL-based animation** to highlight the role of solar energy in ensuring blackout resilience.

Role of Computer Graphics in Problem Representation

Computer graphics is not only about entertainment or gaming—it has profound applications in education, engineering, and awareness-building. Visual simulations allow for experimentation with scenarios that would be impractical, costly, or impossible in the real world. For instance:

- We can simulate a **day-to-night cycle** in seconds, rather than waiting 24 hours.
- We can trigger a **citywide blackout** with keystroke, rather than risking real-world harm.
- We can contrast fossil fuel dependency with solar adaptation in a clear, visual manner.

In the context of this project, computer graphics help represent the problem of energy dependency and its solution through solar adaptation. Users do not need advanced technical knowledge; they only need to observe the simulation to understand the contrast between vulnerable and resilient cities.

Summary of the Problem Context

The problem this project addresses is both simple and profound: cities rely heavily on electricity, and when that electricity fails, society is disrupted. Blackouts highlight the fragility of our energy systems. The adoption of renewable energy, particularly solar power, provides a way to make cities more sustainable and resilient. However, awareness and understanding of these technologies are often lacking.

By using computer graphics to simulate a solar-powered city, this project creates a bridge between complex technical concepts and intuitive public understanding. It places users in a familiar setting—a city with roads, vehicles, buildings, and skies—and lets them directly experience the impact of blackouts and renewable energy. This combination of education, awareness, and technology underscores the relevance and importance of the project in addressing one of the most pressing challenges of modern urban life.

Methods Used:

The development of the *Solar-Powered City Simulation* required a careful combination of programming techniques, computer graphics principles, and design strategies. The goal was to create a virtual city that not only looked visually engaging but also effectively conveyed the importance of renewable energy during blackouts. This section explains the tools, frameworks, and algorithms employed in the project, along with the step-by-step methods used to implement its features.

Choice of Programming Language and Graphics Library

The project was implemented in C++ using OpenGL (Open Graphics Library). The choice of C++ stems from its efficiency, flexibility, and extensive use in computer graphics programming. OpenGL, a widely adopted graphics API, provides powerful low-level access to GPU rendering pipelines, making it ideal for creating animations, geometric shapes, and lighting effects. OpenGL was paired with GLUT (OpenGL Utility Toolkit), which simplifies window management, input handling, and provides utility functions necessary for developing interactive graphics applications. Together, C++, OpenGL, and GLUT formed the foundation of the project.

Project Design Philosophy

The simulation was guided by three key principles:

1. Realism Through Simplification: While photorealism was not the aim, the simulation needed to resemble a real city. The design employed simplified geometric primitives (triangles, rectangles, circles, polygons) to model real-world entities like buildings, vehicles, and airplanes.

2. Dynamic Animation : A city is a living, moving environment. To represent this, animations were included: the sun and moon traverse the sky, clouds drift, vehicles move across roads, and an airplane occasionally appears.

3. Educational Focus: Beyond aesthetics, the simulation had to convey the contrast between blackout conditions and solar-powered resilience. This was achieved through interactive features, such as toggling blackout modes and observing changes in city lighting.

Scene Components and Their Implementation

1. Day and Night Cycle

The sun and moon are drawn as simple filled circles using trigonometric functions. Their position changes across the x-axis over time, simulating motion across the sky.

- The sun's yellow glow dominates during daytime, while the moon replaces it at night.
- A background color gradient is used: light blue during the day, dark navy at night.
- The time of day is tracked using a variable that increments with each frame update.

This cycle provides the foundation for other features, such as when headlights or streetlights should be activated.

2. Cloud Animation

Clouds are constructed using overlapping circles to create fluffy shapes. They move horizontally across the sky at a constant speed.

- Cloud positions are stored in arrays (cloudX[], cloudY[]).
- When a cloud exits the screen boundary, it reappears on the opposite side, ensuring continuous animation.

This introduces variability and liveliness into the otherwise static sky.

3. Buildings and Solar Panels

Buildings are central to the simulation. They are drawn as colored rectangles stacked vertically with small variations in height and color, reflecting the diversity of real urban skylines.

- At night, windows are lit up using small yellow rectangles.
- Solar panels are drawn as dark blue trapezoids or rectangles on rooftops.
- A Boolean flag controls whether buildings receive power from solar panels during a blackout.

The buildings serve as the clearest representation of solar resilience—remaining lit when the rest of the city goes dark.

4. Roads, Vehicles, and Headlights

The road is modeled as a wide, long rectangle stretching horizontally across the scene. Lane dividers are implemented as short, repeated white rectangles.

Vehicles (cars and buses) are drawn using combinations of rectangles (body), circles (wheels), and triangles (details like roofs or noses). Their motion is animated by incrementing x-coordinates, and they loop back to the left side once they exit the screen. Headlights are implemented as filled triangles extending from the car's front. These appear only during nighttime and blackout conditions, giving realism to the simulation.

5. Airplane Animation

The airplane was designed as a stylized polygonal model with a fuselage, wings, and tail. To achieve a realistic effect:

- The airplane enters from one side of the screen.
- It is smaller compared to buildings to reflect perspective.

The airplane adds dynamism and depth to the simulation.

6. Streetlights and Blackouts

Streetlights are vertical poles topped with circular or triangular glowing bulbs. They remain off during the day but illuminate at night.

The blackout feature is a core element of the simulation:

- When triggered, all non-solar-powered lights (buildings and streetlights) are turned off.

- Vehicles still operate with headlights, and if solar mode is enabled, solar-equipped buildings remain illuminated.

This contrast visually demonstrates the vulnerability of cities during blackouts and the advantage of renewable systems.

Algorithms and Animation Techniques

The simulation relies on frame-based animation, where objects' positions and states are updated incrementally with each frame. GLUT's glutTimerFunc() or glutIdleFunc() functions are used to continuously refresh the scene.

Key animation methods include:

- Translation: For moving vehicles, clouds, sun, and moon across the screen.
- Looping: When objects exit one boundary, they reset to the opposite side (clouds, cars).
- Conditional Rendering: Lights, windows, and solar panels appear only under specific conditions (nighttime, blackout).
- Scaling: Used to adjust the airplane size, maintaining proportion with the scene.

Interactivity

User interactivity is a vital part of the project. The keyboard is used to control certain events:

- Toggle Blackout Mode: Turns grid power off, simulating a citywide blackout.
- Enable Solar Power: Switches solar panels on or off to demonstrate their effect during blackouts.
- Exit Simulation: Closes the program.

This interactive component ensures the simulation is not just a passive animation but an educational experience where users can explore "what-if" scenarios.

Color and Lighting Choices

Colors were deliberately chosen to balance realism and clarity:

- Day Sky: Shades of blue with a bright yellow sun.
- Night Sky: Dark navy with a pale white moon.
- Buildings: Multiple colors (red, blue, green, gray) to make the skyline visually diverse.
- Vehicles: Bright colors for visibility against the road.
- Solar Panels: Distinct dark blue to differentiate them from roofs.

Although OpenGL provides advanced lighting models, this project primarily relied on flat colors and 2D lighting effects, which are lightweight yet effective for a simulation of this scope.The project's methods combined programming, computer graphics, and interactive design to create a simulation that is both visually appealing and educational. By employing C++ and OpenGL, the simulation represents a functional miniature city where users can observe day-night transitions, blackout events, and the benefits of solar panels. The structured, modular approach ensured clarity, while animations and interactivity made the experience engaging. Ultimately, the methods used demonstrate how relatively simple graphical tools can convey complex concepts like energy resilience and sustainability, making the project a meaningful intersection of technology and education.

Feature Set:

1. **Day and Night Cycle**
    - Moving **sun** in the sky during the day.
    - **Moon** replaces the sun at night.
    - Background color changes (blue sky → dark navy night).

2. **Moving Clouds**
    - Soft white/gray **clouds** drifting horizontally.
    - Continuous looping motion for realism.
3. **Buildings and Solar Panels**
    - Colorful **buildings** with windows that glow at night.
    - Rooftop **solar panels** highlighted in dark blue.
    - Solar-powered buildings remain lit during blackouts.
4. **Roads and Lane Dividers**
    - **Black/gray roads** spanning the scene.
    - **White dashed lines** as lane dividers.
5. **Vehicles Cars**
    - **Rectangular bodies** with circular wheels.
    - **Headlights** turn on at night.
6. **Airplane Animation**
    - o **Fuselage, wings, and tail** drawn with polygons.
7. **Streetlights**
    - **Vertical poles** with glowing circles on top.
    - Activate only at night.
    - Switch off during blackout simulation.
8. **Blackout Simulation**
    - Triggered by keyboard input.
    - Streetlights and non-solar buildings go dark.
    - Solar-powered buildings remain glowing.
    - Cars' headlights provide minimal light.
9. **Trees**
    - Brown trunks with green foliage.
    - Placed near roads or open spaces.
    - Symbolize sustainability and urban greenery.
10. **Rail Line and Train**
    - Two **parallel rail tracks** across the scene.
    - **Train compartments** as rectangles with windows.
    - Animated locomotive with optional headlight.
11. **Rain and Lightning:**
    - Rain occurs and sky become gray.
12. **Power Poles**
    - **Poles** connected with electric lines.
    - Highlights dependency vs. solar backup.

12. **User Interactivity**
    Keyboard commands for:
    - Toggling blackout.
    - Enabling/disabling solar power.

14. **Modular Code Design**

- Functions divided (e.g., drawCar(), drawBuilding()).
- Easy to maintain and expand with new features.

Future Directions:

The current solar-powered city simulation provides a meaningful representation of how renewable energy can shape modern urban life by integrating day and night cycles, solar-powered buildings, vehicles, streetlights, and blackout scenarios. However, the simulation also opens up opportunities for future expansion to make it more realistic, educational, and technically comprehensive. One clear direction is the incorporation of renewable energy diversity. While the present system highlights solar energy, urban centers also rely on a mix of wind, hydro, and emerging green technologies such as hydrogen fuel cells. Introducing wind turbines on the outskirts of the simulated city or micro-hydro units along rivers would demonstrate how complementary energy sources can ensure greater reliability. This addition could also be tied to seasonal variations, such as more solar energy being available in summer while wind resources dominate in other periods.

Another important improvement involves transportation infrastructure. The simulation already includes cars, airplanes, and a proposed rail system, but future iterations could emphasize green transportation. Electric buses, charging stations, and hybrid vehicles could be animated to showcase the role of electrification in reducing carbon footprints. The railway system could be extended into an electric metro line, reflecting how urbanization trends are moving toward mass public transit systems to reduce congestion and emissions. Expanding the transport network would help users visualize how renewable energy is not limited to buildings but also directly influences urban mobility.The next step would be enhancing environmental realism. While clouds, the sun, and the moon already provide basic atmospheric dynamics, adding seasonal changes such as rainfall, snowfall, or storms would give the simulation greater authenticity. These weather conditions could directly affect solar energy output, with cloudy or rainy days leading to reduced solar power availability, thereby teaching users the importance of energy storage and smart grid systems. In parallel, trees and urban greenery could be expanded to highlight the role of nature in sustainable cities, aligning with global climate adaptation strategies.

Interactivity represents another future avenue. Currently, users toggle between day and night or switch solar panels and blackout modes with simple keystrokes. Future versions could allow users to manage energy resources interactively by deciding how much solar capacity to install, when to activate storage batteries, or how to balance between renewable and grid electricity. This would essentially turn the simulation into a decision-making tool, showing the outcomes of different policy and design choices. Linking these controls with real-time energy consumption graphs could also help communicate complex sustainability concepts in a more engaging manner.

Finally, the future directions for the *Solar-Powered City Simulation* include technical upgrades (3D graphics, real-world data integration), expanded scope (wind, hydro, smart systems), and broader educational applications (gamification, web/mobile deployment). The simulation could eventually be scaled to include comparative case studies, such as how cities like Dhaka, Tokyo, or Berlin integrate renewable energy differently. By continuing to evolve in this direction, the project can serve not only as a creative technical achievement but also as a broader awareness-building tool to encourage sustainable practices among future generations.

Conclusion:

The *Solar-Powered City Simulation* represents a creative integration of computer graphics, sustainability concepts, and urban energy management. By using OpenGL and C++, the project successfully models a miniature smart city environment where solar power and blackout management are central themes. The simulation not only demonstrates technical proficiency in graphics programming but also conveys an important social and environmental message: sustainable energy solutions are vital for resilient urban living. At its core, the simulation captures several essential dynamics of modern cities. The day–night cycle, the movement of vehicles and airplanes, the appearance of solar panels on buildings, and the handling of blackout events all highlight how renewable energy contributes to the stability of urban infrastructure. The blackout handling mechanism, in particular, emphasizes the risks of over-reliance on traditional power sources and the necessity of renewable backup systems. This linkage between technical simulation and real-world urban challenges makes the project meaningful beyond its academic scope.

From a learning perspective, the project strengthened knowledge in multiple domains. Technically, it demonstrated the effective use of OpenGL primitives, transformations, and animation techniques to design a dynamic environment. Conceptually, it reinforced the understanding of renewable energy, urban planning, and environmental sustainability. Working on this project required not only programming skills but also team collaboration, research, and creative design thinking, all of which are valuable in both academic and professional contexts. The project also highlights how computer simulations can play a critical role in education and awareness. Through visualization, abstract ideas such as energy dependency, blackout resilience, and the benefits of solar power become easier to grasp. Instead of simply reading statistics about solar adoption, users can witness a city where solar panels keep the system running even when blackouts occur. This makes the simulation a potential teaching aid for schools, universities, and sustainability campaigns.

Nevertheless, the simulation is just the beginning. As outlined in the Future Directions, there are vast opportunities to make it more advanced and impactful. Moving from 2D to 3D visualization, integrating real-world datasets, and expanding to web or mobile platforms could significantly enhance both realism and accessibility. Moreover, by incorporating features like wind power, battery storage, or smart traffic systems, the project could grow into a comprehensive smart city simulator useful for research and urban planning.

In conclusion, the *Solar-Powered City Simulation* demonstrates how a relatively small-scale programming project can address large-scale societal issues. It is not only a showcase of technical ability but also a meaningful step toward promoting renewable energy awareness. As cities continue to face challenges of energy scarcity, climate change, and increasing urbanization, projects like this remind us that technology and sustainability must advance together. This simulation, though modest in scope, embodies a vision of cities that are cleaner, smarter, and more resilient — a vision worth pursuing in both classrooms and the real world.

Implementation code:

GitHub: https://github.com/nadim249/-Solar-Powered-City-Simulation-Computer-Graphics.git

Screenshots of the project (For each scenario):

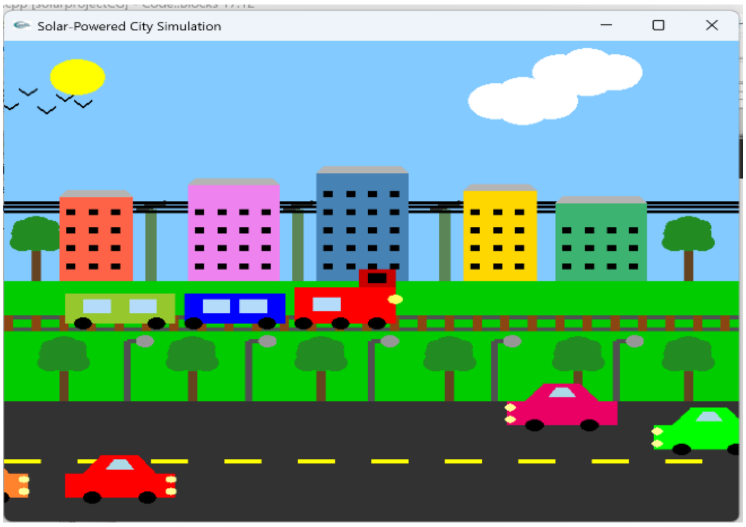

Fig. 1. Daytime urban scene with sun, moving clouds, Train and active vehicles.

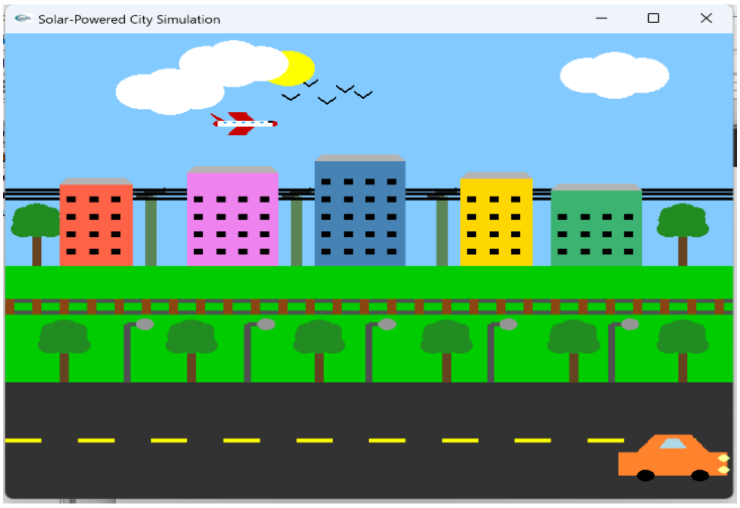

Fig. 2. Airplane flying across the city skyline during the day.

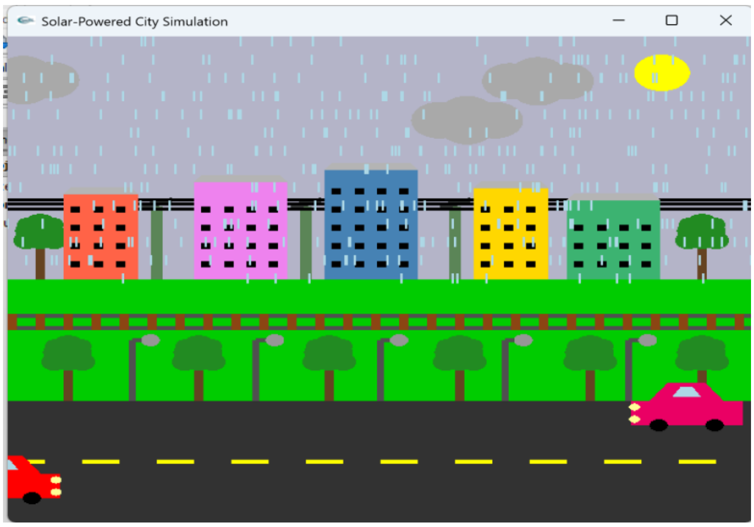

Fig. 3. Rain simulation showing weather effects on the urban environment.

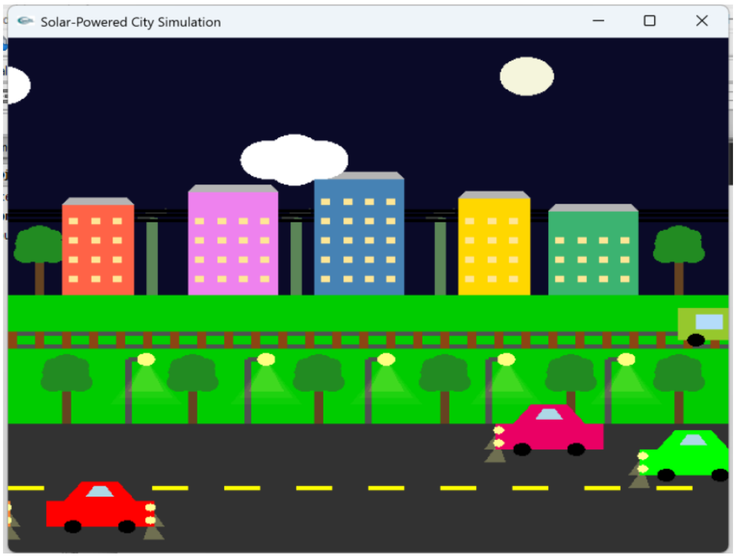

Fig. 4. Nighttime scene with moon, glowing buildings, and vehicle headlights.

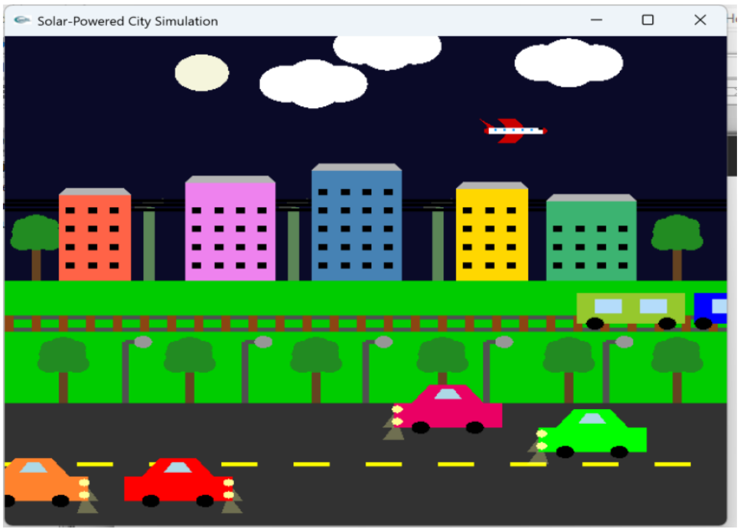

Fig. 5. Blackout simulation showing darkened city with no active grid power.

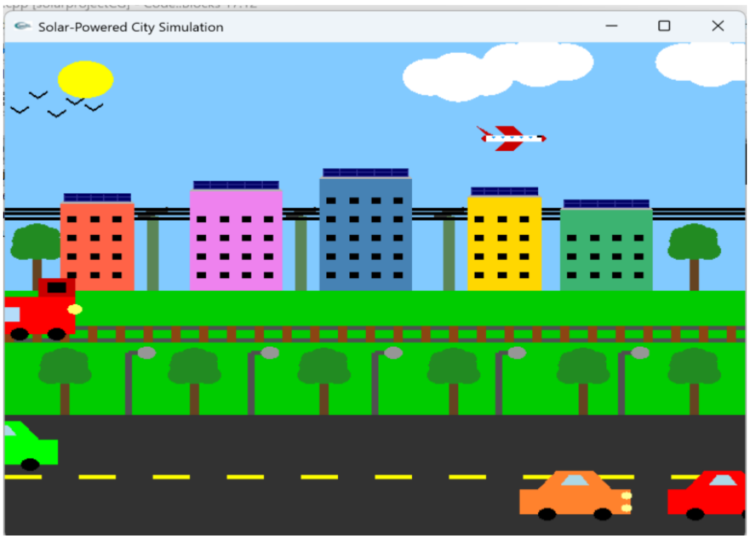

Fig. 6. Solar-powered buildings

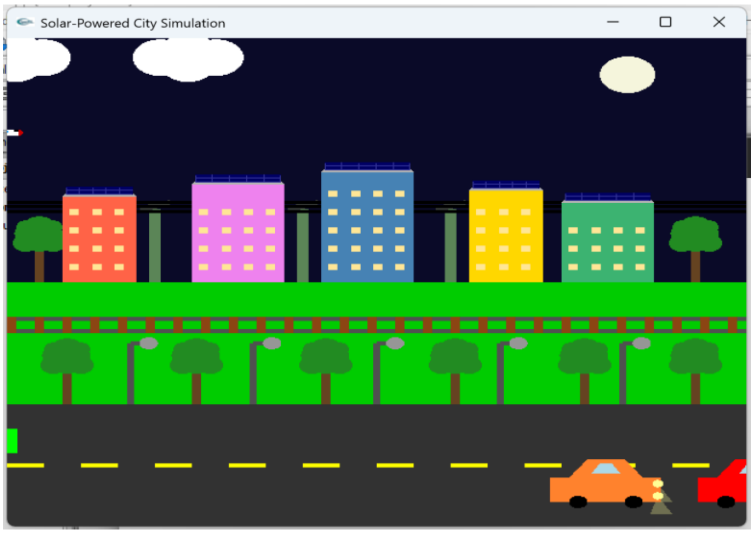

Fig. 7. Solar-powered buildings and streetlights remain active during blackouts.

Link of the implementation in GitHub:

GitHub: https://github.com/nadim249/-Solar-Powered-City-Simulation-Computer-Graphics.git

Reference:

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