Renewable Rhythms: Visualizing Energy Transition through Ethical AI-Data Driven Creative Coding

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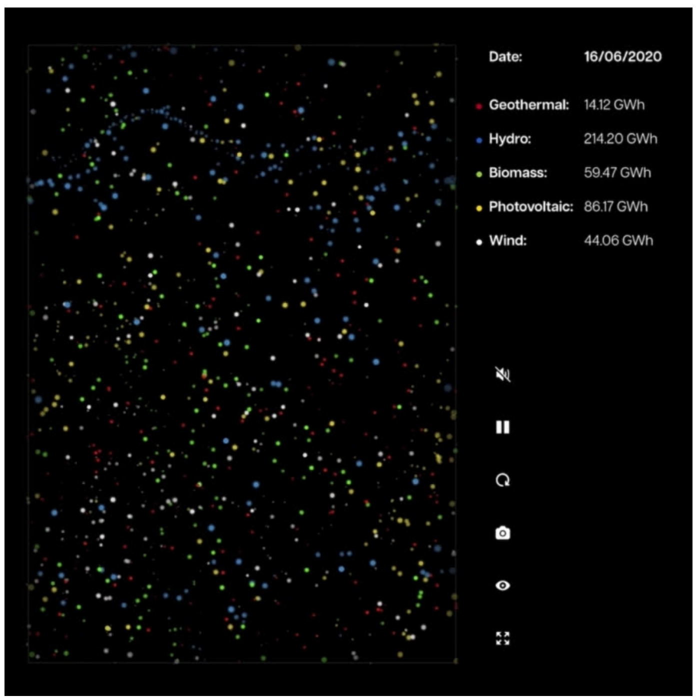

Abstract

Renewable Rhythms is an exploratory project that utilizes public data on renewable energy production in Italy to create a visual narrative. This paper discusses the integration of data-driven methodologies, ethical artificial intelligence (AI), creative coding practices, and mathematical functions to transform raw data into an immersive AI-driven data painting. This data painting reflects the ongoing global transition to renewable energy sources, visualizing the dynamics of energy production from biomass, photovoltaic, hydroelectric, geothermal, and wind sources.

1 Introduction

The global energy sector is undergoing a significant transformation towards renewable energy to mitigate the effects of climate change and reduce dependency on non-renewable resources. Visualizing these changes can enhance public awareness and understanding. Renewable Rhythms employs creative coding to convert renewable energy production data into dynamic visualizations that embody the fluidity and variability inherent in natural processes.

This research is part of The "What If" Project, a collective that explores the intersections between creativity, artificial intelligence, and art to create digital experiences. The data painting "Renewable Rhythms" is available at `https://thewhatifproject.com/renewable/index.html`.

2 Methodology

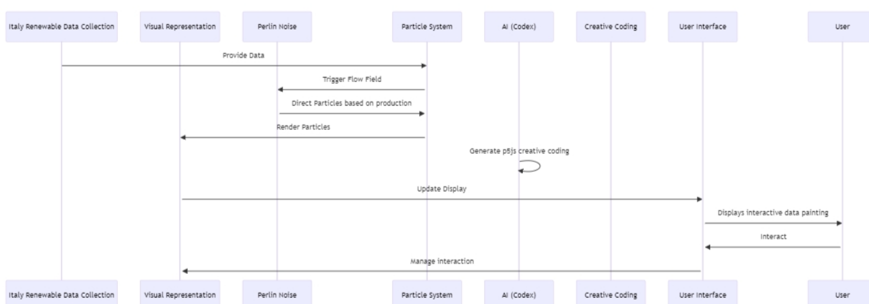

Figure 1: Logical Diagram

2.1 Data Collection

The project uses public Italy datasets detailing daily renewable energy production from various sources, starting from 2019 to the present. These datasets include information on the date, type of energy, and amount of energy generated.

2.2 Data Painting Engine

Each energy type is represented by particles that move across a digital canvas. The movements of these particles are influenced by a flow field, an invisible vector field that directs the particles' paths, akin to natural currents.

2.3 Perlin Noise Function

To simulate natural motion, the project uses Perlin noise—a gradient noise function that creates visually smooth, coherent random patterns. This function is defined as:

$$N(x, y) = \sum_{i=1}^{n} a_i \cdot \text{noise}(f_i \cdot (x, y))$$

where a_i are amplitude coefficients and f_i are frequency coefficients.

2.4 Particle System

Particles vary in speed, size, blur, and color intensity based on the amount of energy produced daily. Higher energy outputs result in more vigorous and lively particle movements, providing a visual representation of energy production levels. The velocity $\mathbf{v}$ of a particle at position $\mathbf{p}$ influenced by the flow field $\mathbf{F}$ can be described as:

$$\mathbf{v}(t) = \mathbf{F}(\mathbf{p}(t))$$

2.5 Ethical AI Contributions

The AI enhances the project by automating parts of the creative coding process. The project leverages the capabilities of Large Language Models (LLMs) to co-generate programming code, working in tandem with human programmers. By utilizing AI for initial code generation and human programmers for subsequent refinements, the project achieves a balance that maximizes both efficiency and creative output.

3 Implementation

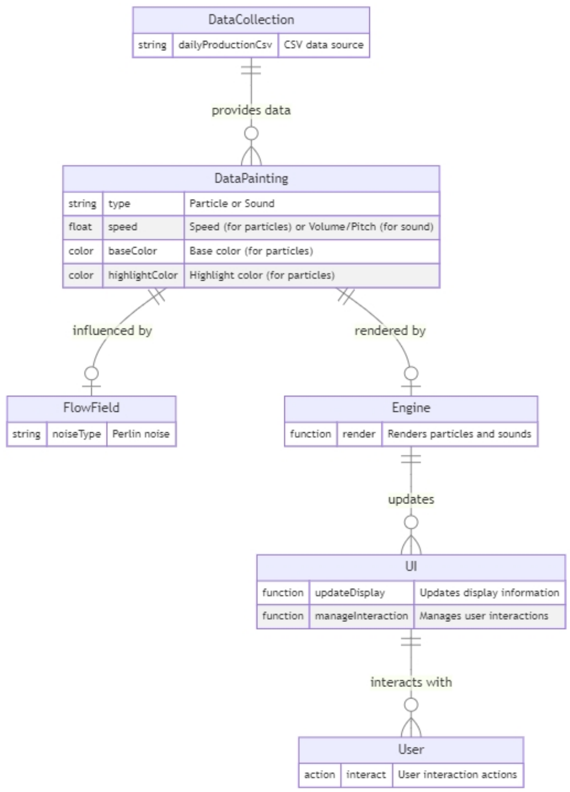

Figure 2: Implementation Diagram

The Data Painting is realized through a synergistic approach that combines the strengths of AI and human expertise. The implementation utilizes a single “creative coding” library approach, p5.js, known for its inclusivity and broad accessibility. This library simplifies complex programming concepts, making the creation of dynamic visual elements more intuitive and suitable for LLM generation (Large-Language-Model).

3.1 Sound System Dynamics

The sound component enriches the interactive experience. Each energy source is associated with a unique sound, and the volume and pitch of the sound vary according to the energy production values:

$$\text{volume} = \text{minVolume} + (\text{maxVolume} - \text{minVolume}) \times \left(\frac{\text{energyValue}}{\text{maxEnergyValue}}\right)$$

$$\text{pitch} = \text{minPitch} + (\text{maxPitch} - \text{minPitch}) \times \left(\frac{\text{energyValue}}{\text{maxEnergyValue}} \right)$$

3.2 Particle Characteristics

Each particle represents a unique measurement of energy produced by different renewable sources. The attributes of particles, such as size, speed, and color, are dynamically adjusted based on the energy production values. For instance:

$$\text{size} = \text{minSize} + (\text{maxSize} - \text{minSize}) \times \left(\frac{\text{energyValue}}{\text{maxEnergyValue}} \right)^{0.3}$$

$$\text{velocity} = \mathbf{v}(t) = \mathbf{F}(\mathbf{p}(t))$$

3.3 Flow Field Generation

The flow field is generated using Perlin noise, ensuring smooth transitions and natural movement. The magnitude and direction of each vector in the flow field are influenced by the noise function:

$$\mathbf{F}(x, y, t) = \nabla \text{Perlin}(x, y, z(t))$$

3.4 Interaction and Control

The visualization allows user interaction through mouse and touch inputs, enabling control over playback, sound, and screen modes. For instance, clicking on the canvas influences the particles' movement, creating a ripple effect:

$$\mathbf{F}_{\text{click}}(x, y) = \mathbf{F}(x, y) + k \cdot \frac{\mathbf{p} - \mathbf{p}_{\text{click}}}{|\mathbf{p} - \mathbf{p}_{\text{click}}|}$$

3.5 Fade Function for Particles

Particles have a limited lifespan and a fade function that determines their transparency over time:

$$\alpha(t) = \max \left(0, 1 - \frac{t}{\text{lifespan}} \right)$$

3.5.1 Color Map for Particles

The color map used to represent different energy sources is as follows:

- Biomass: RGB(154, 205, 50)
- Wind: RGB(211, 211, 211)
- Photovoltaic: RGB(186, 184, 108)
- Geothermal: RGB(207, 16, 32)
- Hydro: RGB(23, 103, 215)

3.5.2 Highlight Colors

Highlight colors are used to emphasize certain states or interactions for each energy source:

- Biomass Highlight: RGB(57, 255, 20)
- Wind Highlight: RGB(255, 250, 250)
- Photovoltaic Highlight: RGB(255, 215, 0)
- Geothermal Highlight: RGB(255, 69, 0)
- Hydro Highlight: RGB(118, 182, 196)

3.6 Glow Effect

Particles exhibit a glow effect that varies based on their velocity intensity:

$$\text{glowIntensity} = \frac{\|\mathbf{v}\|}{\text{maxspeed}}$$

$$\text{glowSize} = \text{size} \times (1 + 0.5 \times \text{glowIntensity})$$

$$\text{glowAlpha} = 70 \times \text{glowIntensity}$$

4 Results

The interactive canvas allows users to visualize the fluctuating nature of renewable energy production. The use of color intensity, particle speed, and flow dynamics effectively conveys the energy output's variability and the transition towards more sustainable energy sources.

5 Discussion

This project demonstrates the potential of integrating creativity with data science and AI to educate and engage the public on critical issues such as energy sustainability. The visual and interactive elements help in making complex data comprehensible and engaging for a broad audience. The human aspect of programming and design remains essential, ensuring that the AI's capabilities are directed towards meaningful and ethically grounded applications.

6 Conclusion

Renewable Rhythms highlights the power of data visualization in storytelling, particularly in the context of significant global challenges. The project not only raises awareness about renewable energy but also showcases the synergy between technology, art, and human creativity. By emphasizing the importance of data as a tool to communicate and sensitize public opinion on the energy transition, it also underlines the critical role of human oversight in the realm of AI, ensuring that technology enhances rather than replaces the human touch.

References

[1] Perlin Noise, *Wikipedia*, `https://en.wikipedia.org/wiki/Perlin_noise`

[2] P5JS, *p5js.org*, `https://p5js.org/`

[3] Transparency Report Data, *Terna*, `https://www.terna.it/`