Using Generative Models to Create a Visual Description of Climate Change

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Abstract. The discrepancy between the rapid dissemination of information and its effective communication underlies the phenomenon of scientific denialism. Given the rapid strides in AI generative models, this project explores the domain of knowledge visualization to portray weather data through a visually captivating representation of Rio de Janeiro's climate evolution up to the year 2100. The use of prompt engineering over climate models has yielded promising outcomes in image generation, yet challenges remain in ensuring deterministic accuracy in image construction.

Keywords: Generative Models · Knowledge Visualization · Climate Change

1 Introduction

In a survey conducted by Yale in 2021, 47% of Americans said they do not believe that global warming will harm them personally [21]. Despite scientific advancements that highlight and substantiate ongoing climate changes, this statistic reveals the significant gap between the access of information and the acceptance among the general population.

To combat scientific denialism, the World Economic Forum introduced the acronym SUCCES based on the book "Made to Stick" by Chip and Dan Heath [20]. According to this framework, it is crucial to share information in a **simple**, **unexpected**, **credible** manner, presenting the data in a **concrete** way, using analogies and metaphors to connect with the **emotional** aspects of the audience, shaping scientific knowledge into compelling **stories** [8].

Thus, when it comes to climate change, creating accurate visual representations of abstract information becomes interesting in fostering a stronger connection and raising awareness of the magnitude of this problem.

Therefore, this paper presents the construction of a cultural product, i.e., an audiovisual work that has the purpose of large-scale consumption, presenting

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climate data and scientific statements in a concrete way with strong emotional appeal aiming to enhance acceptability and engagement among the audience.

Based on models of weather factors provided by CMIP6, a initiative of the World Climate Research Programme (WCRP) [16], climate factors up to the year 2100 will be visualized within a unified artistically pictorial landscape based on Guanabara Bay, Rio de Janeiro - one of the most susceptible areas to the impacts of climate shifts [3]. This project named Vigilante, in reference to residential security personnel, seeks to allow viewers to envision a possible future under new conditions.

This study aligns with the field of Knowledge Visualization (KV), a relatively young discipline that explores "all (interactive) graphic means that can be used to develop or convey insights, experiences, methods, or skills" [13–15].

Historically, the evolution of graphic information can be traced from the Middle Age manuscript culture in Europe to contemporary computer-based visualization [31]. With the rapid and significant progress of generative AI models, the synthesis capabilities of these algorithms combined with a systematic data-driven approach can create alternative means to represent abstract information, advocating a novel mode of engaging with data through pictorial images that ensures greater comprehensibility for the audience.

Prominent examples of this models includes DALL-E [30], Mid Journey [27], and Stable Diffusion [33], which are capable of generating complex synthetic images based on descriptive prompts. Also, applications such as Deforum [9] and Kaiber.ai [23] enable the creation of videos by concatenating multiple images from generative models.

In light of these considerations, we aim to address the following research question: "Is it effective to use current generative models based on prompt engineering to represent deterministic data?"

Our contributions are as follows:

(i) Introduce the use of pictorial images for information representation.
(ii) Developing a pipeline for systematic and data-driven utilization of generative models as tools for innovative information visualization.
(iii) Present a graphical representation depicting the climate transformation in Rio de Janeiro over the upcoming century.

2 Literature Review

The use of computers to generate creative works is an area that has been studied and validated in academia [28]. When it comes to knowledge visualization, the literature suggests that generated images should provide assistance for reasoning, reflection, and the exploration of connections in new ways, in order to facilitate new discoveries based on shared insights [13]. It is also understood that pictorial representations reveal significant aspects of the history of visual culture and knowledge [12].

Regarding art made with generative models that address environmental issues, some artists have created visual representations of climate change and its consequences in landscapes more sensitive to global warming such as glaciers and coral reefs with the aim of raising awareness about the cause [4,19].

3 Methodology

Drawing on the concept that offering comprehensible and accessible data can enhance individuals' awareness of climate changes and promote action for the cause [32], our poetical proposal is to produce a video where each frame reflects the conditions of climate variables predicted during sunset, where the colors conveying the tranquility and melancholy of the end of the day while also reflects the uncertainty of the future.

Observing the engagement in discussions about climate change on social media, 56% of users from Generation Z (born after 1996) stated that they interacted with this topic in the past week, compared to 44% of users from other generations, namely Millennials (born between 1981–1996), Gen X (born between 1965–1980), Boomers (born between 1946–1964), and older [35]. Also, 69% of Generation Z social media users stated that climate change content made them feel anxious about the future, with one of the causes being the dissatisfaction with the insufficient amount of current actions being taken [35].

As "the 'aura' of the digital object is fundamental to how it is received by its audiences" [22], recognizing the feelings of anxiety and dissatisfaction can be interesting in driving action in favor of the environment, developing a project that provides foundation and tools for Generation Z to express their opinions and viewpoints beyond their own generation [18]. An overview of the project's pipeline can be seen in Fig. 1.

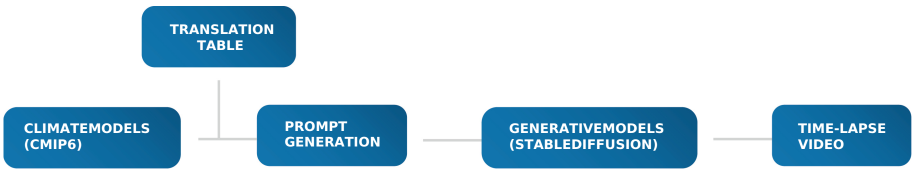

Fig. 1. Pipeline to create images based on satellite data.

According to the Global Climate Observing System (GCOS), there are essential climate variables (as listed in Table 1) that help us understand the behavior of the global warming [5].

Utilizing the surface atmosphere variables models from CMIP6 Amon table with monthly frequency (*mon*), with geographic coordinates -23, -42, the data spanned from 2015 to 2100 representing a fossil fuel-based developed world focused on rapid global economic expansion (SSP5 scenario) [2].

As observed in Fig. 2, the increasing trend in average temperature, coupled with higher levels of precipitation, creates a conducive environment for flooding and landslides [3,24]. The rise in solar radiation and atmospheric pressure further exacerbates urban heat islands. The possibility of abrupt pressure changes also leads to an increase in the occurrence of storms in the region [17].

Table 1. Climate variables and models.

GCOS Variable	CMIP6 Model [6]	Prompt Variable
Precipitation	Precipitation (pr)	Precipitation, Sky conditions
Pressure	Sea Level Pressure (psl)	Sky conditions
Radiation Budget	Surface Downwelling Clear-Sky Longwave Radiation (rldscs)	Sea level
Temperature	Near-Surface Air Temperature (tas)	Windchill
Wind Speed	Near-Surface Wind Speed (sfcWind)	Windchill, Wind

Prompt Engineering. Although current image generative models are primarily developed for natural language understanding, achieving desired results hinges on an individual's ability to accurately describe the object [25,29]. Several guidelines are proposed for the methodological production of high-quality images, as the following template [29]:

[Medium] [Subject] [Artist(s)] [Details] [Image repository support]

In order to represent deterministic information, we created prompts from the model data. Numerical values were translated into descriptive English terms, aligned with meteorological language and human climate perception (Fig. 3). For more complex scenarios involving multiple factors, translations draw from researcher-described situations rather than raw data abstraction. For artistic aims, other prompt engineering criteria rely on frequently employed keywords for visual descriptions as represented in Table 2.

The use of prompts to represent a same location with specific climate variations can lead to out-of-context elements in the image defined as hallucinations [26].

When comparing real landscapes that have identical climate data, the visual composition is not strictly the same between the environments, possessing a randomness that can be likened to the hallucinate process of generative models. However, it can challenge the goal of assigning deterministic meaning and maintain a visually coherent sequence while accurately depicting the imposed changes.

Temporal Connection. Once the method for generating high-quality images that visually represent the data was established, it became necessary to create images that maintain the connection between subsequent frames in order to present the predictions as a video.

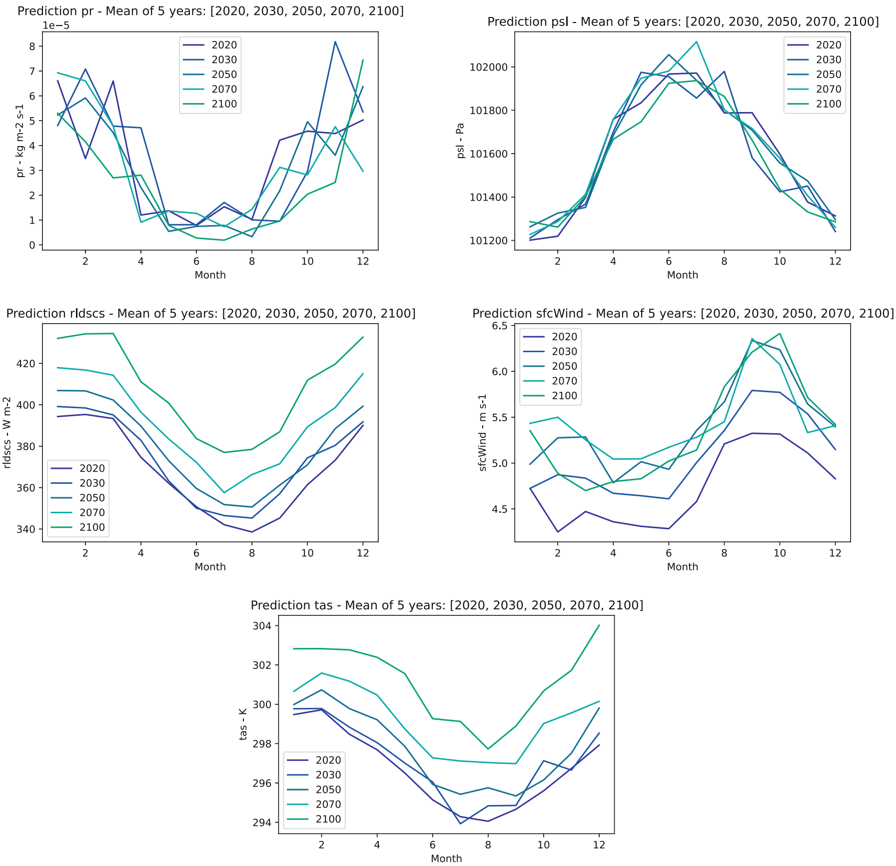

Fig. 2. Precipitation, Pressure, Radiation Budget, Wind Speed, and Temperature distribution over years.

To enhance control over hallucination and temporal transitions, a viable strategy to stimulate or repress this effect involves fine-tuning the interplay between the image_strength and cfg_scale parameters. These parameters determine the degree of impact the initial image wields on the diffusion process and how closely it adheres to the prompt text, respectively.

In this study, it was experimented the creation of videos using time-lapse approach, where each individually frame was generated using Stable Diffusion API v1.5 or xl-beta-v2.2.2 based on the previous image generated with random seed, parameter that ensures reproducibility and control over the generated outputs. This accumulation factor of images enables the representation of subtle climate changes that occur over time, such as rising sea levels, but it also accentuates certain aspects of the image that distort the environment.

Table 2. Keywords to create prompt variations [7,34].

Medium	**Subject**	**Artist**	**Details**	**Image Repository Support**
A photograph of	Guanabara Bay,	VSCO, Pinterest,	figurative style = renaissance style, hyperrealism,	Quality Booster = 4k, award-winning photograph,
	{Precipitation},		{Time of the day},	90s
	{Sky conditions},			
	{Sea level},			
	{Windchill},			
	{Wind},			

Variable	**Values**
{Precipitation}	'dry day, clear sky', 'moderate rain, few clouds', 'storm, cloudy day', 'heavy storm, thunders, lightning'.
{Sky conditions}	'vibrant', 'overcast', 'melancholic atmosphere', 'lightning, darker atmosphere'.
{Sea level}	'calm sea', 'sea waves invading the sand', 'sea waves invading the sidewalk', 'sea invading the street and reaching houses', 'sea taking over the city'.
{Windchill}	'nice weather, lush vegetation', 'hot weather', 'dry vegetation', 'arid landscape'.
{Wind}	'calm wind', 'fresh wind', 'soft wind', 'strong wind, wind vegetation', 'hurricane, destroyed vegetation'.
{Time of the day}	'sunrise', 'morning', 'golden hour', 'sunset', 'night'.

4 Results

In the context of controlled generative image production, specific configurations play a pivotal role in shaping the visual outcomes. The video featured in [10] showcases the results obtained.

When the image_strength is equal to zero and the seed value is fixed, the generated images do not exhibit visual correlation among themselves when subtly altering the prompt. Conversely, when alternating between different prompts, consistently similar images are generated in accordance with the prompts used (Fig. 4).

For image_strength parameter with values above 0.75, the changes in the image are too subtle, not being able to distinguish the individual data from each frame. Consequently, after multiple iterations, the image is distorted by noise, as observed in Fig. 5.

When the image_strength parameter is set from 0.7 (Fig. 6), a temporal correlation is established while the generated images assume the characteristics described by the prompt. However, with an increasing number of iterations, the

Fig. 3. Prompt modifications on the field *subject* to generate images with different seeds: (Fig. 1) clear sky, lush vegetation, few boats in the water, calm sea; (Figs. 2 and 3) cloudy sky, destroyed vegetation, drown boats in the water, lightning, stormy sea; (Fig. 4) clear sky, vegetation covered in snow, frozen water, sunset lights, calm sea.

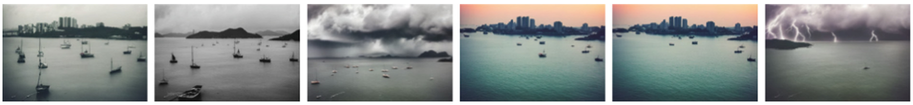

Fig. 4. Stable Diffusion, text-to-image, seed = 2792954258.

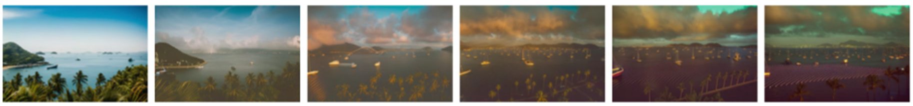

Fig. 5. Stable Diffusion, image-to-image, image strength = 0.75.

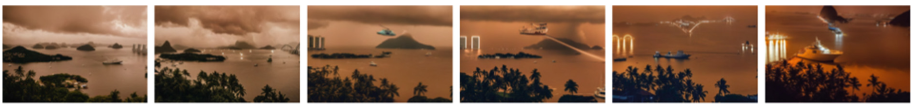

Fig. 6. Stable Diffusion, image-to-image, image strength = 0.7.

Fig. 7. Stable Diffusion, Image-to-Image, image strength = 0.6.

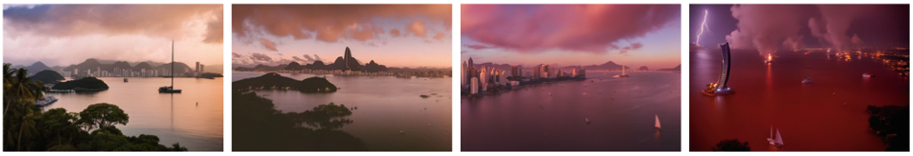

Fig. 8. Stable Diffusion, image-to-image, multiple frame transition.

model tends to hallucinate, generating random elements that do not relate to the environment, which can be desirable in some contexts, such as the artistic field. In one of the experiments, during testing with an image_strength of 0.6, the number of boats exponentially increased occupying the scene completely (Fig. 7).

From then on, we adopted a combination of the parameters with random seed while incorporating multiple frames for transitions. Following a series of iterative experiments, an optimal configuration materialized: a three-frames transition involving two distinct model versions [xl-beta v2.2.2, v1.5, v1.5] accompanied by image_strength values [0.8, 0.7, 0.7] and cfg_score values [3, 6, 9]. The outcome entailed the production of images exhibiting heightened thematic interconnectedness, coupled with an improved capacity to capture nuanced variations in individual climates (Fig. 8).

5 Discussion

The application of generative models in crafting data-driven knowledge visualizations, particularly for individual images, has demonstrated a remarkable potential. In cases where images are generated without previous frame, a resemblance to actual landscapes emerges, capturing the essence of the visual representation found in data. Nevertheless, the introduction of temporal connectivity presents challenges.

While the inclusion of previous images in the generation process enables consistency between frames, it often sacrifices the accurate portrayal of individual image characteristics, being traded off due to unintended hallucinations from the essence of the original landscape when previous images are not heavily included.

The prompt engineering approach, while contributing to the accessibility of the models, has inherent linguistic limitations. Climatic description in natural language is location-sensitive. Describing a Brazilian city in English introduces linguistic and visual biases due to translation.

Due to the process of describing the data in natural language, when processed by generative models, they may not interpret the linguistic nuances exactly as intended. Consequently, the created visual representations may exhibit significant bias stemming from the author's perception of the acquired information.

Moreover, these models provide a gateway to the realm of imagination, rendering them a valuable asset in scientific communication. Their use in academia allows for visual communication of findings, bridging the gap between complexity and accessibility. However, despite these advancements, deterministic accuracy remains an elusive aspiration through this strategy.

6 Conclusions and Future Work

The Vigilante project generated interesting results by observing the progression of climatic events in the city of Rio de Janeiro. However, due to the hallucinatory capabilities of generative models, they currently lack the ability to assume a deterministic nature.

Deepfake techniques present a promising means to gain more control over hallucination during image generation [36]. Implementing elements of control can further ensure that the outcomes of this work do not distort potential realities of the near future. In conjunction with these changes, the establishment of objective evaluation metrics would allow the assessment of multiple models, climate variables and keyword combinations, automating the evaluation of generated results in comparison to desired outcomes.

To augment realism, training generative models on image databases specifically tailored for each ecosystem is essential. There is also a growing interest in developing mask technologies capable of maintaining overall coherence, especially when generating images that depict particular scenarios under diverse weather conditions.

Research suggests that, regardless of their technical prowess, the mere awareness that a creation is computer-generated can diminish its artistic value [1]. Hence, gauging the emotional resonance of the generated videos and evaluating the impact of such visualizations on human understanding and perception are crucial for effective communication. Undertaking field research to acquire a comprehensive grasp of the audience's perspectives and concerns will enable more tailored visualizations, fostering a deeper connection with viewers.

Lastly, an exemplar of the transformation of the acquired content into a cultural product can be accessed at [11].

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