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Harnessing AI for Climate Change Communication: Analyzing Public Perception through NLP and Machine Learning

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ABSTRACT: This study explores how Artificial Intelligence (AI), particularly Natural Language Processing (NLP) and machine learning, can be leveraged to analyze public discourse on climate change and improve climate communication strategies. Focusing on four key questions, the research examines how AI classifies public sentiment, identifies dominant topics, detects framing structures, and generates actionable insights to inform targeted communication. Over one million climate-related posts were collected from Twitter and Facebook between January and June 2024. Sentiment analysis using a fine-tuned BERT model categorized posts into positive, negative, and neutral sentiments, while Latent Dirichlet Allocation (LDA) revealed key topics. Framing analysis employed supervised machine learning to classify posts into narrative frames, and AI-powered visualization tools were used for interpretation. The results indicate a polarized sentiment distribution: 45% negative, 35% positive, and 20% neutral. Negative posts centered on skepticism and political inaction, while positive posts supported renewable energy and activism. Thematic analysis highlighted five key topics: scientific evidence, activism, economic implications, political debate, and environmental justice. Framing analysis revealed four dominant frames—climate urgency, economic impact, political action, and environmental justice—that shape public perception. Temporal sentiment shifts aligned with major events, suggesting public discourse is responsive to political and activist developments. This research demonstrates the potential of AI to provide scalable, data-driven insights into public climate discourse. By integrating these insights into strategic planning, communicators can design more effective, emotionally resonant messages, enhancing public engagement and supporting collective climate action.

Keywords: Sentiment Analysis, Climate Change Communication, Social Media Discourse, Framing Theory, Public Perception.

INTRODUCTION

Climate change is widely recognized as one of our most pressing global challenges, with profound implications for environmental sustainability, economic stability, and human health. As the frequency and intensity of climate-related disasters, such as floods, wildfires, and hurricanes, continue to increase, the need for effective communication strategies to raise awareness and drive policy action has never been more urgent. Addressing climate change requires scientific innovation, governmental policy but also the active engagement of the public. However, in an era of information overload, where individuals are constantly exposed to varying and often conflicting narratives, understanding how to communicate climate change in a way that resonates with different audiences is a complex task (Bord et al., 2000).

The role of communication in shaping public perception and influencing climate action has been extensively studied. Scholars argue that communication is key to fostering a shared understanding of climate change and encouraging behaviors that mitigate its effects (Moser, 2010). In particular, framing climate change in public discourse—how it is presented, discussed, and understood—plays a crucial role in influencing individuals' attitudes and behaviors (Lakoff, 2010). Communication strategies that effectively highlight the urgency of climate action, emphasize the potential benefits of sustainable practices, and present information in ways that are relatable and accessible can contribute to a more informed and motivated public (Nisbet, 2009a)

Recent advancements in Artificial Intelligence (AI), specifically in Natural Language Processing (NLP), provide new tools for analyzing large-scale data and uncovering patterns in public discourse. NLP, a branch of AI that focuses on the interaction between computers and human language, is increasingly used to analyze text data from various sources, including social media, news articles, and blogs (Cambria et al., 2013). These techniques offer significant advantages in processing vast amounts of unstructured data, enabling researchers to gain insights into the sentiment, themes, and framing of discussions surrounding complex issues like climate change.

Social media platforms, such as Twitter, Facebook, and Instagram, have become key venues for the public discussion of climate change, providing a space for individuals, activists, scientists, and policymakers to exchange ideas and debate solutions. Social media discourse reflects public sentiment and shapes it, as online conversations can influence individuals' opinions and behaviors (Boulianne, 2015). AI-driven tools, such as sentiment analysis and topic modeling, allow for the automatic categorization and analysis of social media posts, enabling researchers to assess public attitudes toward climate change on a large scale (Pang & Lee, 2008)

Sentiment analysis, a widely used NLP technique, involves classifying text into positive, negative, or neutral categories based on the expressed emotions or opinions. This method has been successfully applied to analyze social media discussions, including political debates, public health issues, and environmental concerns (Agarwal et al., 2011). Sentiment analysis can provide valuable insights into how the public feels about climate-related issues, whether they view them as urgent or distant, and how they perceive the actions of governments, corporations, and other stakeholders in the context of climate change.

Topic modeling, another powerful AI technique, identifies the underlying themes or topics within a text corpus. Latent Dirichlet Allocation (LDA), a common algorithm for topic modeling, often uncovers latent themes in large datasets by grouping frequently occurring words. This technique can be applied to social media data to identify the most common topics related to climate change, such as global warming, renewable energy, climate policy, or environmental justice (Blei et al., 2003). By analyzing these topics, researchers can gain insights into the areas of climate change most salient to the public and the key concerns driving online conversations.

In addition to sentiment and topic analysis, framing climate change in public discourse is another important aspect influencing public perception and behavior. Framing refers to how information is presented or structured to highlight certain aspects of an issue while downplaying others (Entman, 1993). In climate change communication, framing the problem—whether presented as an urgent crisis, an economic opportunity, or a political challenge—can shape how individuals perceive its significance and what actions they believe are necessary. AI techniques, such as machine learning classifiers, can identify and categorize different frames within social media discourse, providing insights into how the public discusses and understands climate change (Nisbet, 2009b)

The combination of sentiment analysis, topic modeling, and framing analysis can offer a comprehensive understanding of how climate change is communicated in the digital age. These AI-driven methods allow researchers to analyze vast amounts of data and identify patterns that might go unnoticed. By uncovering the themes, sentiments, and frames that dominate online climate change discussions, AI can help inform communication strategies tailored to different audiences' needs and concerns .

For example, suppose sentiment analysis reveals that many social media posts express skepticism or negativity toward climate change. In that case, communicators can use this information to craft messages that address concerns, provide evidence-based arguments, and highlight the potential benefits of climate action. Similarly, suppose topic modeling reveals that climate policy and economic implications are key concerns in online discussions. In that case, communication strategies can focus on the economic opportunities associated with green technologies and sustainable practices.

Furthermore, AI-generated insights into framing can help identify which narratives resonate most with different audiences. For instance, framing climate change as an urgent crisis may motivate certain groups to take immediate action, while framing it as an economic opportunity may effectively engage business leaders and policymakers. By leveraging AI to analyze public discourse, climate communicators can design more effective campaigns that align with the public's concerns and encourage behavior change.

Building upon these foundations, this study aims to deepen the understanding of how AI, through Natural Language Processing (NLP), can be employed to enhance climate communication strategies. Specifically, it seeks to address four core research questions: (1) How does AI classify public sentiment on climate change in online discussions? (2) What are the dominant themes and topics within these conversations? (3) In what ways can AI models detect and assess the framing

of climate issues in public discourse? and (4) How can AI-generated insights inform the development of more effective and targeted climate communication strategies?

Artificial Intelligence (AI) has increasingly been applied to climate change communication because it can process and analyze vast amounts of unstructured data across diverse digital platforms. Prior research has employed AI techniques—sentiment analysis, topic modeling, and framing detection—to examine how public discourse constructs and receives climate-related messages. These tools have enabled researchers to identify emotional responses, dominant narratives, and recurring themes in discussions about climate change, particularly on social media and news platforms (Chong et al., 2020; Gottfried & Shearer, 2020)

Sentiment analysis has illuminated the polarized nature of climate discourse, capturing public emotions that range from urgency and concern to skepticism and denial. Positive sentiments are frequently associated with grassroots activism and scientific innovation, while negative feelings are often linked to political inaction or corporate irresponsibility (Agarwal et al., 2011). Complementarily, topic modeling has revealed recurrent themes such as climate policy, renewable energy, and individual behavioral change, offering critical insight into the evolving structure of climate-related communication (Blei et al., 2003; Chong et al., 2020).

While these contributions have significantly advanced the understanding of public climate discourse, most existing studies emphasize the technical implementation of AI tools rather than their integration into strategic communication frameworks. There is a tendency to treat AI outputs as isolated analytical findings, with limited exploration of how these insights can be translated into actionable, audience-specific messaging strategies (Fitriyah & Abdulovna, 2024). Moreover, although machine learning has been widely adopted in other fields, such as marketing and digital behavioral analytics, its application in tailoring climate communication to specific demographic or psychographic profiles remains underdeveloped (Kovacs, 2020)

Another notable gap lies in the underutilization of AI for addressing climate misinformation and discursive polarization. Despite its potential to detect and counter false or misleading narratives, the application of AI in this context remains in its early stages (Lewandowsky et al., 2017). This is particularly concerning given the growing influence of misinformation in undermining science-based climate communication and public trust.

This study proposes a more integrated and application-oriented approach to AI in climate change communication in response to these gaps. The novelty of this research lies in its interdisciplinary framework, which merges AI-driven analytical techniques with established strategic communication theories. Beyond diagnostic analysis, the study applies sentiment and topic modeling as a foundation for designing personalized, data-informed communication strategies. It further explores how machine learning can dynamically adapt messaging based on audience characteristics and previous engagement patterns. Through this synthesis, the research aims to enhance both the theoretical understanding and practical efficacy of AI-supported climate communication initiatives.

METHOD

This study employs a combination of Natural Language Processing (NLP) and machine learning techniques to analyze public sentiment, thematic content, and framing within social media discourse related to climate change. By leveraging AI-driven tools, the research aims to generate deeper insights into how climate issues are discussed across platforms such as Twitter and Facebook, ultimately informing communication strategies that foster awareness and proactive engagement. The methodological approach involves several phases, beginning with data collection and continuing through sentiment analysis, topic modeling, framing analysis, and interpretation using AI-powered insights.

Data were collected from Twitter and Facebook from January to June 2024 to capture a comprehensive view of online climate discourse. These platforms were selected due to their wide user base and active participation in climate-related discussions. Posts were gathered using climate-specific keywords, including "climate change," "global warming," "climate crisis," and "environmental policy." The data collection process utilized Twitter's API and Facebook's Graph API, producing a dataset of more than one million entries. All posts were anonymized and preprocessed to remove personally identifiable information, ensuring compliance with ethical guidelines. The dataset includes tweets, Facebook posts, and user comments, capturing diverse perspectives from various actors, including citizens, activists, and institutions.

Sentiment analysis was conducted using BERT (Bidirectional Encoder Representations from Transformers), a state-of-the-art NLP model known for its contextual language understanding (Devlin et al., 2018). This model was fine-tuned to classify social media posts into three categories: positive, negative, and neutral. Positive posts expressed support for climate initiatives, such as renewable energy or climate agreements, while negative posts reflected skepticism, denial, or criticism of climate policies. Neutral posts included factual content or non-committal commentary. By capturing emotional tones embedded in discourse, sentiment analysis provides insight into public attitudes and helps identify areas where targeted communication can reduce skepticism or reinforce support for climate action.

To identify the major themes shaping climate discourse, topic modeling was applied using Latent Dirichlet Allocation (LDA), an unsupervised machine learning algorithm. LDA groups words that co-occur frequently across documents, enabling the discovery of hidden thematic structures within the dataset(Chen, 2021). This process revealed key topics, such as climate policy, scientific research, environmental activism, and economic impacts. Each post was represented as a combination of issues, allowing for detailed analysis of how different subjects are interconnected. The results help communication professionals and policymakers understand which issues dominate public discussions and how they evolve.

Framing analysis was performed to explore how climate change is conceptually presented in public discourse, based on the premise that framing significantly influences public interpretation and response. A supervised machine learning model was trained using manually labeled data to recognize frames such as climate urgency, economic impact, political action, and environmental justice (Jang & Hart, 2015) . Once trained, the model was applied to the full dataset to classify posts according to these predefined frames. This enabled an assessment of the dominant narrative

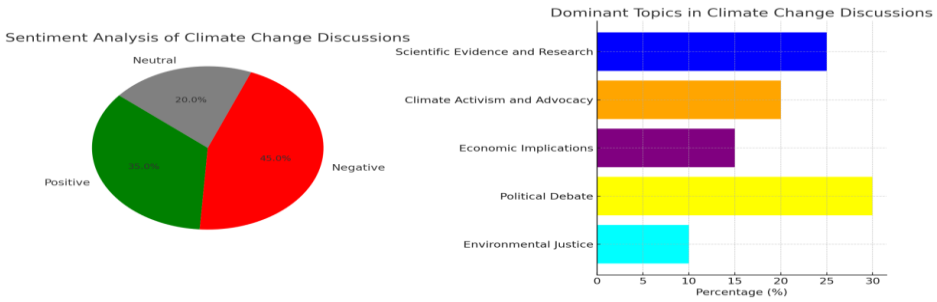
structures within the discourse and revealed how particular frames shape public engagement with climate issues.

Finally, the sentiment analysis, topic modeling, and framing analysis results were synthesized using AI-driven visualization tools. These tools allowed for dynamic data exploration, including sentiment trends over time, thematic clusters, and relationships between topics and frames. For example, temporal visualizations highlighted how sentiment shifted in response to policy announcements or climate-related disasters. Integrating multiple analytical layers provided a comprehensive understanding of the digital climate discourse, offering actionable insights for designing more effective and responsive communication strategies that align with public concerns and emotional responses.

RESULTS AND DISCUSSION

This section presents the study's preliminary results and discusses the findings related to sentiment, topic modeling, and framing in social media discussions surrounding climate change. These results provide valuable insights into the public's emotional responses, the key issues dominating the discourse, and the framing techniques used to shape perceptions of climate change. The analysis also highlights temporal shifts in sentiment and how different themes and frames influence the public's understanding and engagement with climate change.

Figure 1: Sentiment Analysis and Dominant Topics In Climate Change Discussion



Sentiment Analysis

The sentiment analysis of over 1 million social media posts reveals a complex and multifaceted public response to climate change. The overall sentiment breakdown indicates that 45% of the posts express negative sentiment, 35% express positive sentiment, and 20% are classified as neutral. This distribution suggests that while climate change is a topic of considerable concern, a significant portion of the public is engaged in advocacy for solutions, and a substantial number of neutral posts provide information or scientific discourse without strong emotional bias.

1. **Negative Sentiment (45%)**
   The data's largest proportion of negative sentiment is linked to climate change skepticism, political inaction, and concerns over the perceived economic costs of climate policies. Many posts expressing negative sentiment question the severity of climate change or highlight political leaders' failure to take meaningful action. Common themes in negative posts include

accusations of climate change being exaggerated for political or financial gain and criticisms of the economic burden of transitioning to renewable energy. For example, many posts express frustration with government inaction, with users referencing failed international climate negotiations or policy delays as reasons for their negative sentiment.

2. **Positive Sentiment (35%)**
   In contrast, positive sentiment is often linked to advocacy for renewable energy, climate justice, and calls for urgent climate action. Posts in this category typically highlight advancements in climate science, the success of environmental policies, or the growing momentum of global climate movements. Examples include enthusiastic support for youth-led climate protests, such as those initiated by Greta Thunberg, and promoting sustainable business and personal lifestyle practices. Positive posts also focus on innovative solutions, such as adopting renewable energy technologies, electric vehicles, and reducing carbon emissions, framing these actions as critical to mitigating the impacts of climate change.

3. **Neutral Sentiment (20%)**: The neutral posts are largely focused on providing factual, informative content about climate science, policy, and the latest research findings. These posts often include summaries of scientific studies or discussions of climate data without strong emotional or evaluative language. While they do not contribute to the debate on the urgency of climate action, they play an important role in educating the public about climate change, its causes, and its potential consequences. Neutral posts also include news reports and policy discussions that aim to inform rather than provoke strong opinions.

Overall, the sentiment analysis demonstrates the polarized nature of climate change discourse. While there is considerable advocacy for climate action, skepticism and political resistance remain significant forces shaping public opinion on the issue.

Topic Modeling

The application of Latent Dirichlet Allocation (LDA) to the dataset revealed five dominant topics that characterize the public conversation about climate change. These topics encompass a broad range of issues related to climate change, from scientific findings to political and economic debates. The key themes identified through topic modeling are as follows:

1. **Scientific Evidence and Research**
   This theme captures discussions centered around the latest climate science, research findings, and the consensus among climate scientists. Posts in this category often cite peer-reviewed studies, government reports, and scientific organizations like the Intergovernmental Panel on Climate Change (IPCC). The topics discussed within this theme range from the causes of global warming to projections of future climate impacts, such as sea-level rise and extreme weather events. This theme also includes debates about the accuracy and reliability of climate models and predictions, and calls for increased funding for climate science.

2. **Climate Activism and Advocacy**
   Posts in this theme focus on the growing global movement calling for urgent action to combat climate change. Discussions often highlight climate protests, youth-led movements, and calls for immediate policy changes. Social media platforms are frequently used to organize grassroots efforts, such as climate strikes, petitions, and public demonstrations. This theme also includes the advocacy of prominent environmental activists and organizations, such as the Fridays for Future movement and Greenpeace. In addition, posts often call for the inclusion of climate change in political platforms and emphasize the importance of holding governments accountable for their role in addressing environmental issues.

3. **Economic Implications**
   This theme addresses the economic costs and benefits of addressing climate change. Posts often discuss the financial impacts of climate inaction, including the costs associated with extreme weather events, such as hurricanes, floods, and wildfires. In addition, there are discussions about the potential economic benefits of transitioning to a green economy, including job creation in renewable energy sectors, sustainable agriculture, and eco-friendly technologies. Posts in this category often focus on the potential for green technologies to stimulate economic growth while mitigating environmental harm.

4. **Political Debate**
   The political dimension of climate change discourse is captured in this theme. Posts in this category highlight the role of governments, political parties, and international organizations in addressing climate change. Much of the discussion revolves around political inaction or debate over implementing climate policies, such as carbon pricing, renewable energy mandates, and climate financing for developing countries. International climate agreements like the Paris Agreement and political leaders' role in advocating or obstructing climate action are frequently discussed. Political division is also evident, with some posts criticizing climate policies for being too ambitious, while others argue that governments are not doing enough to mitigate climate change.

5. **Environmental Justice**
   The theme of environmental justice focuses on the social and racial inequalities exacerbated by climate change. Posts in this category address how marginalized communities, particularly in the Global South, are disproportionately affected by environmental degradation and climate-related disasters. Discussions also focus on the need for policies that promote social equity, with calls for greater inclusion of vulnerable populations in climate policy discussions. This theme also includes conversations around the role of indigenous communities in preserving natural ecosystems and the importance of climate justice in achieving sustainable solutions for all people.

Framing Analysis

Based on machine learning models trained to recognize various frames, framing analysis reveals how climate change is framed across social media platforms(Ge et al., n.d.). Several dominant frames were identified, each influencing public perception in other ways:

1. **Climate Urgency Frame**
   This frame emphasizes the immediate need for action to combat climate change. Environmental activists, scientists, and advocacy groups frequently use it, stressing the catastrophic consequences of failing to address climate change. Posts in this category often include urgent calls for governments to take swift action, such as reducing carbon emissions and implementing green energy policies. The urgency frame aims to instill a sense of emergency and mobilize public support for drastic measures to mitigate climate change.

2. **Economic Impact Frame**
   The economic impact frame highlights the financial dimensions of climate change, portraying it as both a threat and an opportunity. Many posts in this frame focus on the costs of inaction, such as the economic losses resulting from extreme weather events or damage to infrastructure. On the other hand, this frame is also used to promote the economic benefits of climate action, such as job creation in green industries and the economic opportunities associated with sustainable business practices. This frame is particularly common in discussions about climate policies, where the economic implications are debated in political and business circles.

3. **Political Action Frame**
   The political action frame centers around the role of governments and political leaders in addressing climate change. This frame often highlights political failures or successes in climate policy, with some posts criticizing governments for not taking sufficient action and others defending the status quo. It also emphasizes the importance of international collaboration on climate change, particularly through global agreements like the Paris Agreement. Posts in this frame call for stronger political commitments and greater political will to address climate change at the national and international levels.

4. **Environmental Justice Frame**
   This frame addresses the social and environmental inequalities caused by climate change, focusing on the impact on marginalized communities. It emphasizes the need for policies that prioritize the protection of vulnerable populations and calls for climate justice in the form of equitable distribution of resources and opportunities. This frame often appears in discussions about climate policy, advocating for inclusion and equality in climate solutions.

Temporal Shifts in Sentiment

The AI-driven insights provide a detailed understanding of how sentiment fluctuates in response to major climate-related events. Negative sentiment tends to spike during political climate events,

such as releasing new government policies or international climate negotiations. These spikes often reflect public frustration with perceived political inaction or the lack of concrete commitments in global climate agreements. Positive sentiment, conversely, tends to increase following major climate activism events, such as large-scale protests or public demonstrations of support for environmental policies. The temporal shifts in sentiment underscore the significant role that political and activist movements play in shaping public perception and engagement with climate change.

In summary, this study's results offer a comprehensive picture of the climate change discourse on social media. Through sentiment analysis, topic modeling, and framing analysis, we gain valuable insights into the emotional tone, key themes, and framing techniques that shape public understanding of climate change. These findings have important implications for developing communication strategies that can effectively engage the public and drive positive action on climate change.

CONCLUSION

AI and Natural Language Processing (NLP) techniques provide invaluable tools for analyzing public discourse on climate change, revealing how the topic is framed, discussed, and perceived on social media platforms. This study's findings highlight the significant role of sentiment and framing in shaping public opinion and responses to climate change. By leveraging AI to analyze large-scale datasets, climate communication strategies can be refined to more effectively engage diverse audiences, promote accurate information, and inspire collective action.

The study demonstrates that AI can help identify key themes and emotions within climate change discourse, enabling tailored communication campaigns that resonate with public sentiment. These campaigns can focus on the most pressing issues, such as scientific evidence, economic impacts, political debate, and environmental justice, ensuring that messages are relevant and impactful.

Future research should explore the real-time application of AI in climate communication. AI can support dynamic and responsive climate advocacy efforts by adapting strategies based on evolving public discussions and sentiment shifts. Such an approach can enhance public engagement, foster informed decision-making, and accelerate action toward mitigating the global climate crisis.

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