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Generative Artificial Intelligence: Techniques, Applications, Challenges, and Future Directions

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Abstract:

A class of artificial intelligence models known as "generative AI" is able to produce original text, images, audio, video, and code. Advanced deep learning architectures such as Transformer-based large language models (LLMs), Variational Autoencoders (VAEs), and Generative Adversarial Networks (GANs) power it. This essay examines the foundational ideas, cutting-edge methods, applications in various industries, difficulties, moral dilemmas, and potential applications of generative artificial intelligence.

Keywords: Generative AI; GANs; Diffusion Models; Transformers; Synthetic Data; Ethics; Low-Resource Languages

Introduction:

The goal of the artificial intelligence subfield known as "generative AI" is to develop models that can produce fresh data samples. These models can generate new, realistic content by learning from the data that already exists. In recent years, generative AI has become increasingly important due to the growth of large datasets and powerful computational resources.

Key Techniques / Architectures:

- Overview, variations, advantages, and disadvantages of Generative Adversarial Networks (GANs)
- Diffusion models and variational autoencoders (VAEs)
- Generative models based on transformers (such as large language models)
- Compositional Generative Models: smaller, composed models as opposed to monolithic models

Applications of Generative AI:

- Natural Language Processing: text generation, summarization, translation
- Image / Video Generation and Editing
- Synthetic Data for training and data augmentation
- Multimodal AI (text + image, etc.)
- Research / Science: assisting in experiments, hypothesis generation, simulations

Survey of Recent Literature:

- Generative AI: A Systematic Review and Applications (S. Sengar et al., 2024)
- Advances in Large Language Models (Hagos et al., 2024)
- Rise of Generative AI in Science (Ding et al., 2024)
- Risks of Generative AI in Academic Writing (Jain & Jain, 2023)

Challenges & Issues:

- Reliability / Hallucinations
- Bias, Fairness, Ethics (data, representation)
- Computational cost, energy consumption
- Data privacy & copyright
- Legal & social implications

Future Directions / Opportunities:

- Efficient Model Training, Distillation, Lightweight Models
- Better evaluation metrics and benchmarks
- More work in low-resource languages, domains
- Multimodal authenticity and consistency
- Responsible AI: transparency, explainability, accountability

Conclusion:

With its potent tools for industry, science, and creativity, generative AI has completely changed the field of AI research. But it also presents serious technical and ethical problems. Building dependable, accountable, and inclusive generative systems that reduce risks and benefit society should be the main goal of future research.

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