

HOW LARGE-SCALE AI MODELS TRANSFORM SDG RESEARCH

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PRESENTATION OVERVIEW

This presentation explores how large-scale AI models can transform research and implementation of the UN Sustainable Development Goals (SDGs), focusing on:

- Brief Introduction
- Technical Evolution: From AI to Large Language Models
- Pathways for LLMs to Enable the SDGs
- Extended Reading Materials

PART 01

BRIEF INTRODUCTION

GLOBAL SUSTAINABILITY FRAMEWORK

- The UN's **2030 Agenda for Sustainable Development**, adopted in 2015, establishes a blueprint for global action to achieve peace and prosperity by 2030.
- The 17 interconnected Sustainable Development Goals cover three main dimensions:

Economic Dimension

- ✓ End poverty in all its forms
- ✓ Zero hunger
- ✓ Quality education
- ✓ Decent work and economic growth

Social Dimension

- ✓ Gender equality
- ✓ Reduced inequalities
- ✓ Health and well-being
- ✓ Quality education for all

Environmental Dimension

- ✓ Climate action
- ✓ Water under pressure
- ✓ Land degradation
- ✓ Wildlife protection

Interconnected Nature:

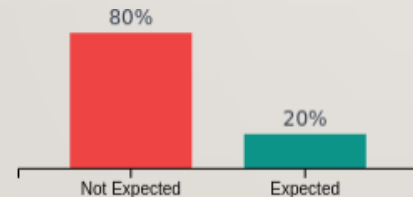
SDGs are not separate or sequential, but an integrated framework where progress in one area often depends on progress in others.

- Addressing climate change requires coordinated action across multiple sectors
- Quality education supports economic growth and sustainable development
- Environmental protection is essential for poverty reduction

COMPLEX SUSTAINABILITY CHALLENGES

- Only <20% of the SDGs are expected to be achieved by 2030, according to the Sustainable Development Report 2025.
- This highlights the urgency of accelerating progress, especially through innovative technologies like AI.

SDG Achievement Projection



Less than 20%

of the 17 SDGs expected to be achieved by 2030

Urgency Assessment

⚠ Accelerated action needed across all goals

💡 Innovative technologies like AI required

Without accelerated action, the world is on track to miss the 2030 Sustainable Development Goals. ^①

AI AT THE CROSSROADS OF GLOBAL SUSTAINABILITY

- Artificial Intelligence and Large Language Models stand at a critical intersection, transforming how we approach complex sustainability challenges while offering unprecedented opportunities for global impact.
- Transformative AI & LLM Capabilities
 - Deep learning, pre-trained models, and multimodal technologies enable processing of complex data, pattern recognition, and generation of innovative solutions for sustainability challenges.
- AI-SDG Integration Potential
 - AI and LLMs can accelerate SDG implementation through data-driven insights, personalized solutions, and optimized resource allocation across all 17 goals.

"AI and LLMs offer unprecedented opportunities to transform how we approach the Sustainable Development Goals, enabling innovative solutions that were previously unattainable."

PART 02

TECHNICAL EVOLUTION: FROM AI TO LARGE LANGUAGE MODELS



TECHNICAL EVOLUTION: FROM AI TO LARGE LANGUAGE MODELS

- What is LLM?
- Historical development of LLM
- LLM Training Procedure
- LLM Inference
- Evaluating LLMs
- Open Challenges

2.1 WHAT IS LLM?

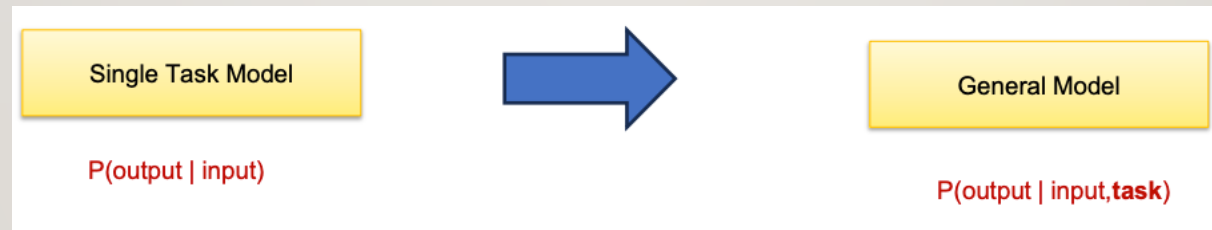
LANGUAGE MODELS

GPT 2 – GENERALIZING TO UNSEEN TASKS

- LMs can be used for different tasks by pre-training a “base” model and then fine-tuning for the task(s) of interest
- Practical Issues:
 - Too many copies of the model
 - Need for large-scale labeled data for fine-tuning
- Multi-task Training?
 - Data remains a challenge
 - Humans don't need such large volumes of data to learn – can we do better?
- Train a model that can perform NLP tasks in a zero-shot manner

TASK SPECIFICATIONS

- Primary shift comes from modeling assumptions from single-task to general model
- Task descriptions may be provided as text – for example, translate this French text to English

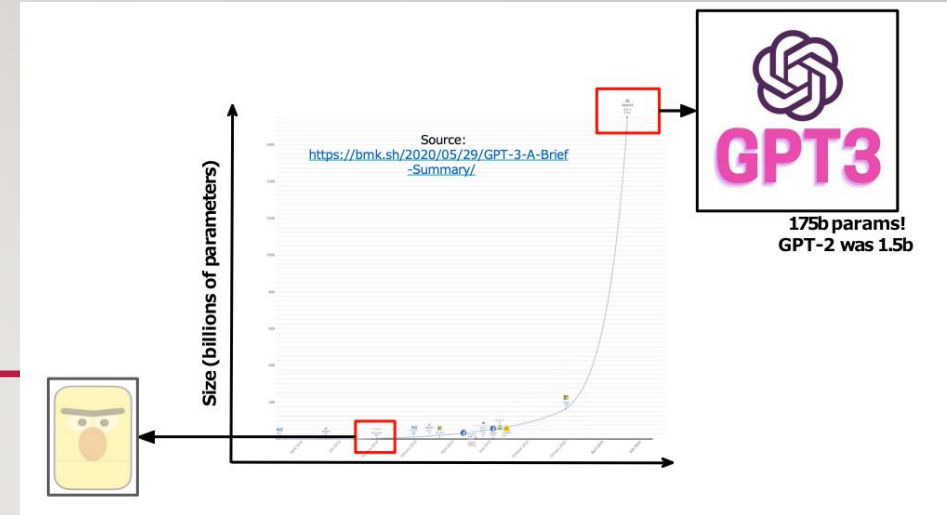


WHAT MAKES SUCH AN LM WORK ?

- Diverse training data
 - Model can do many disparate tasks with no training at all!
- Scaling model capacity and data
 - Scaling improves the perplexity of the LM and improves performance
 - With scaling laws, we can make decisions on architecture, data, hyperparameters by training smaller models (Kaplan,2020)
 - The effect of some hyperparameters on big LMs can be predicted before training
- Idea
 - Train a few smaller models
 - Establish a scaling
 - Select optimal hyper param based on the scaling law prediction

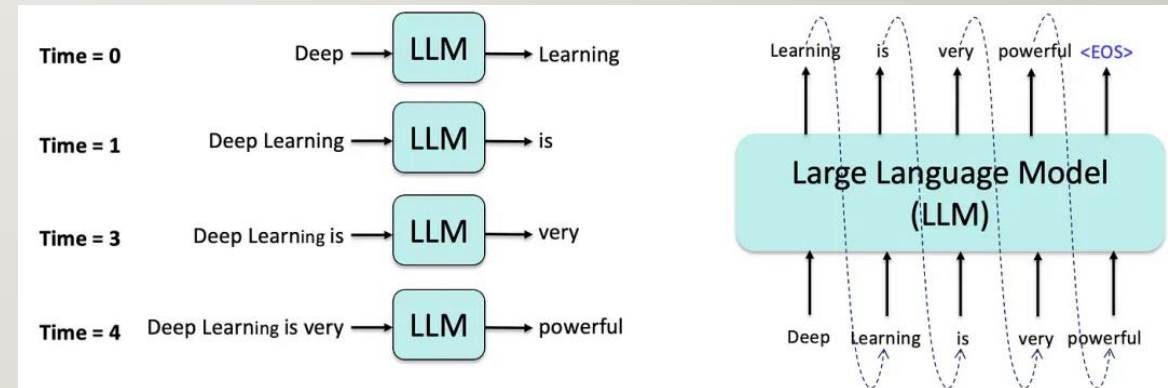
GPT-3

- Emergent abilities
 - not present in smaller models but is present in larger models
 - Do LLMs like GPT3 have these ?
- Findings
 - GPT-3 trained on text can do arithmetic problems like addition and subtraction
 - Different abilities “emerge” at different scales
 - Model scale is not the only contributor to emergence – for 14 BIG-Bench tasks, LaMDA 137B and GPT-3 175B models perform at near-random, but PaLM 62B achieves above-random performance
 - Problems LLMs can’t solve today may be emergent for future LLMs

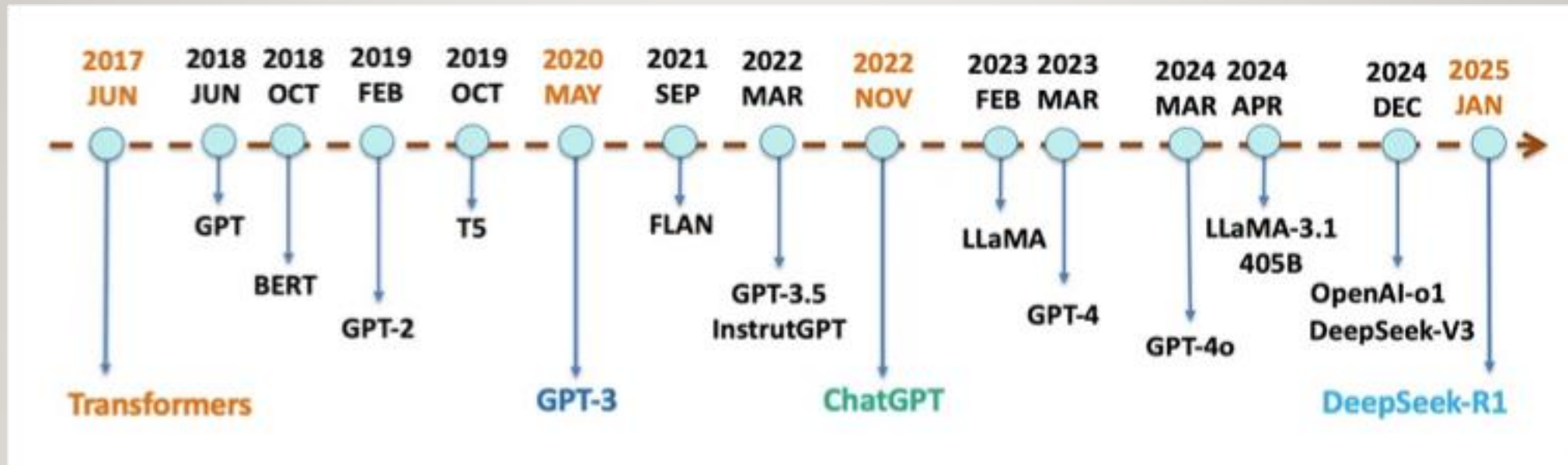


LARGE LANGUAGE MODELS

- Language models that have many parameters (over 1B) and can perform multiple tasks through prompting
- Remember the simple n-gram language model
 - Assigns probabilities to sequences of words
 - Generate text by sampling possible next words
 - Is trained on counts computed from lots of text
- Large language models are similar and different
 - Assigns probabilities to sequences of words
 - Generate text by sampling possible next words
 - Are trained by learning to guess the next word

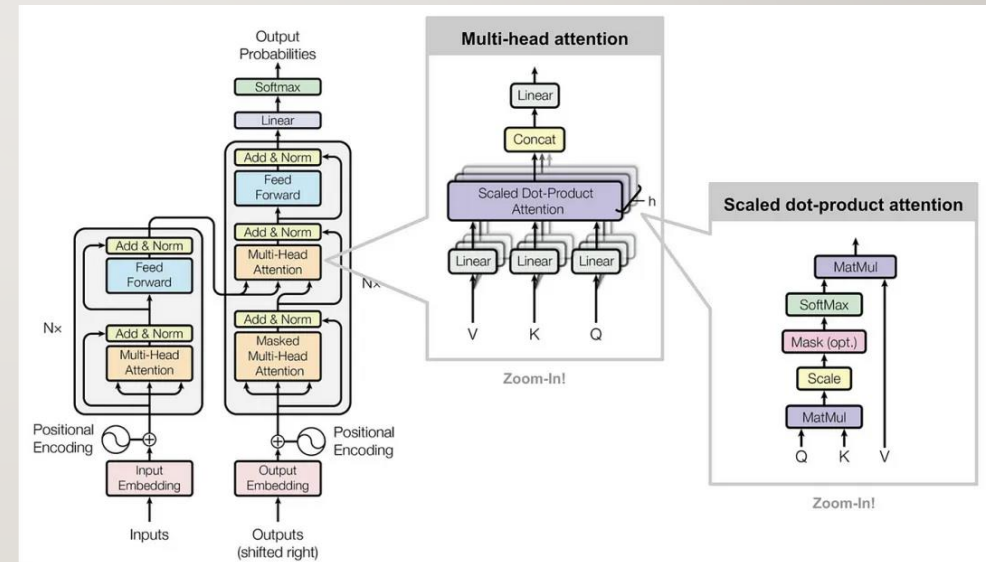


2.2 HISTORICAL DEVELOPMENT OF LLM



Transformer Revolution (2017)

- "Attention is All You Need", Vaswani et al. 2017
- Limitations of Predecessor Models (RNNs & LSTMs)
 - **Long-range dependencies:** Effectively capturing relationships between distant elements in a sequence
 - **Sequential processing:** Inherent sequential computation hindered parallelization, leading to inefficient training
- Utilizing a self-attention mechanism for global context modeling and parallel computation
- Revolutionizing the field and paving the way for modern large language models (LLMs) like BERT and GPT



Pre-Training Transformer (2018–2020)

- BERT: Bidirectional Contextual Understanding (2018), Google
 - Groundbreaking model using the Transformer encoder that achieved state-of-the-art performance across a wide range of NLP tasks.
 - GPT models
 - showcasing the power of autoregressive architectures and generative capabilities.
 - opened up new possibilities for applications such as content creation, conversational agents, and automated reasoning, achieving near-human performance across a wide range of tasks
- Dataset Size: Larger models require massive datasets for pre-training.
 - Computing Resources: The availability of powerful hardware (such as GPUs and TPUs) and distributed training techniques
 - Efficient Architectures: Innovations such as mixed-precision training and gradient checkpointing have reduced computational costs

Post-training Alignment: Bridging The Gap Between AI And Human (2021–2022)

- SFT

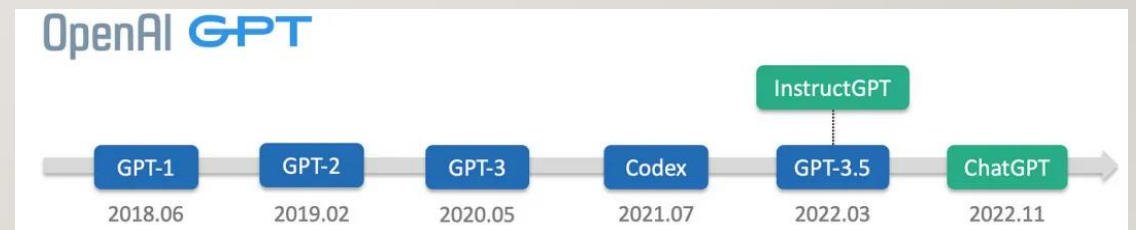
- Training the model on high-quality input-output pairs, or demonstrations, to teach it how to follow instructions and generate the desired outputs.
- These demonstrations are carefully curated to reflect expected behaviors and outcomes, ensuring the model learns to generate accurate and contextually appropriate responses.

- RLHF

- Unlike SFT, which requires humans to write the complete output, RLHF involves ranking the outputs generated by multiple models according to quality. This approach allows for more efficient data collection and annotation, significantly enhancing scalability.

- ChatGPT

- In March 2022, OpenAI released GPT-3.5, an upgraded version of GPT-3 with the same architecture but improved training and fine-tuning.
- Better following of instructions through improved data, reduced hallucinations (although not completely eliminated), and a more diverse and updated dataset to generate more relevant and context-aware responses.



Multi-modal Models - Connecting text, images, and more (2023-2024)

- **GPT-4V**

- interpret images, generate captions, answer visual questions, and infer contextual relationships in visuals. making it valuable in fields such as healthcare (e.g., analyzing medical images) and education (e.g., as interactive learning tools).

- **GPT-4o**

- Transcribe audio, describe video, or synthesize text into audio. Real-time interaction and enhanced creativity

Prompt:
Describir la imagen en 20 idiomas diferentes



GPT-4V:

1. Inglés: This is a beautiful view of Machu Picchu in Peru.
2. Español: Esta es una hermosa vista de Machu Picchu en Perú.
3. Francés: C'est une belle vue de Machu Picchu au Pérou.
4. Alemán: Dies ist eine schöne Aussicht auf Machu Picchu in Peru.
5. Italiano: Questa è una bella vista di Machu Picchu in Perù.
6. Português: Esta é uma bela vista de Machu Picchu no Peru.
7. Ruso: Это красивый вид на Мачу-Пикчу в Перу.
8. Chino: 这是秘鲁马丘比丘的美丽景色。
9. Japonés: これはペルーのマチュピチュの美しい景色です。
10. Coreano: 이것은 페루의 마추 피추의 아름다운 경치입니다.
11. Hindi: यह पेरू के माचू पिचू का सुंदर दृश्य है।
12. Árabe: هذا منظر جميل لماتشو بيتشو في بيرو.
13. Turco: Bu, Peru'daki Machu Picchu'nun güzel bir manzarasıdır.
14. Griego: Αυτή είναι μια όμορφη θέα του Μάτσου Πίκτσου στο Περού.
15. Hebreo: זהו נוף יפה של מאצ'ו פיצ'ו בפרו.
16. Sueco: Det här är en vacker vy av Machu Picchu i Peru.
17. Noruego: Dette er en vakker utsikt over Machu Picchu i Peru.
18. Danés: Dette er en smuk udsigt over Machu Picchu i Peru.
19. Holandés: Dit is een prachtig uitzicht op Machu Picchu in Peru.
20. Polaco: To piękny widok na Machu Picchu w Peru.

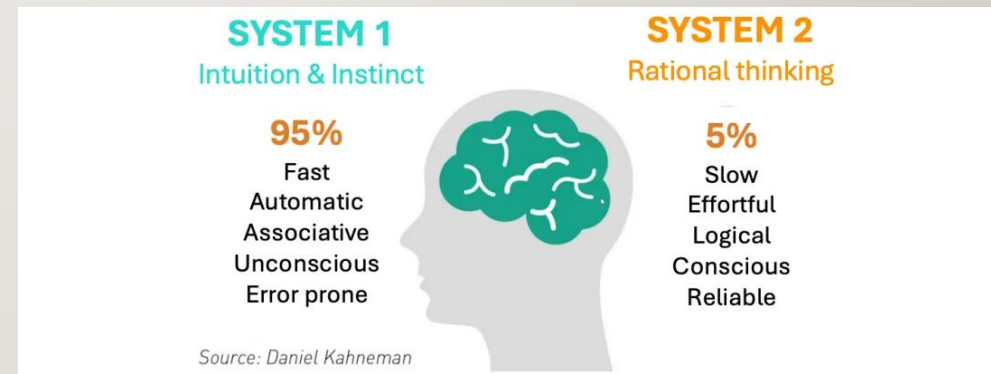


Open Source / Open Weight Models (2023–2024)

- Open Weight LLMs
 - provide publicly accessible model weights with minimal restrictions. This enables fine-tuning and adaptation, while keeping the architecture and training data private. They are suitable for rapid deployment.
 - make the underlying code and structure publicly available. This allows for comprehensive understanding, modification, and customization of the model, fostering innovation and adaptability.
- Community-driven innovation: Platforms like Hugging Face foster collaboration, and tools like LoRA and PEFT enable efficient fine-tuning.

Reasoning Models (2024)

- Shift from simple pattern recognition to more logical and structured thought processes was influenced by the dual-process theory of cognitive psychology
- Distinguishes between "System 1" (fast, intuitive) and "System 2" (slow, analytical) thinking.
- **OpenAI-o1 (2024), OpenAI-o3(2025)**



Provides exceptional problem-solving skills through structured internal reasoning processes and sets new standards in complex mathematical and programming tasks

Cost-efficient Inference Model: Deepseek-R1 (2025)

- (December 2024) DeepSeek-V3 emerged as a cost-effective, open-weight LLM, setting a new standard for AI accessibility. DeepSeek-V3 rivals leading solutions like OpenAI's ChatGPT, but with a significantly lower development cost, estimated at approximately \$5.6 million.
- (January 2025) DeepSeek-R1-Zero & DeepSeek-R1 demonstrate exceptional inference capabilities at minimal training cost. Leveraging advanced reinforcement learning techniques, these models demonstrate that high-performance inference can be achieved without the enormous computational overhead typically associated with cutting-edge AI.

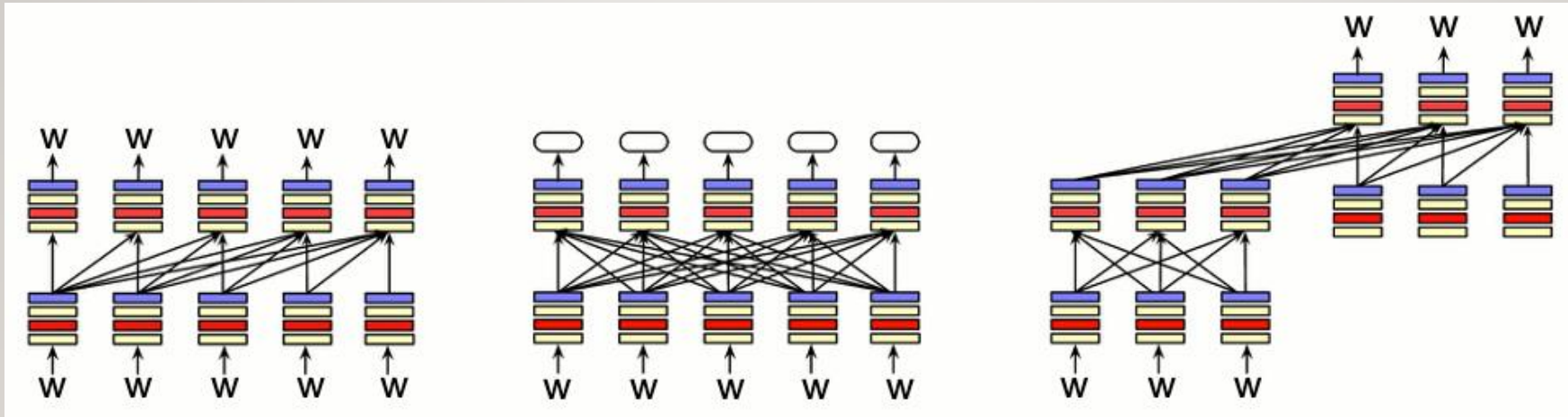
DeepSeek-R1 challenges established norms in the AI field, democratizing access to advanced LLMs and fostering a more competitive ecosystem. Its affordability and accessibility are expected to drive increased adoption and innovation across various industries.

2.3 LLM TRAINING PROCEDURE

The development of state-of-the-art Large Language Models (LLMs) is not a single training step but a complex, multi-stage pipeline. Each stage serves a distinct purpose, moving the model from a general-purpose knowledge base to a helpful and aligned AI assistant.

- Pre-training
- Supervised Fine-tuning -SFT
- Alignment via RLHF
 - Training a Reward Model -RM
 - Reinforcement learning - RL

THREE ARCHITECTURES FOR LARGE LANGUAGE MODELS



- Decoders

- GPT, Claude, Llama, Mixtral

- Encoders

- BERT family, HuBERT

- Encoder-decoders

- Flan-T5, Whisper

DECODERS

- What most people think of when we say LLM
 - GPT, Claude, Llama, DeepSeek, Mistral
 - Pre-training: Auto-regressive Language Modeling
 - It takes as input a series of tokens, and iteratively generates an output token one at a time.
 - Left to right (causal, autoregressive)
 - Stable training, faster convergence
 - Better generalization after pre-training

ENCODERS

- Pre-training: Masked Language Models (MLMs)
- BERT family
- Trained by predicting words from surrounding words on both sides
- Are usually finetuned (trained on supervised data) for classification tasks

ENCODER-DECODERS

- Pre-training: Masked Span Prediction
- Trained to map from one sequence to another
- Very popular for:
 - machine translation (map from one language to another)
 - summarization
 - speech recognition (map from acoustics to words)

Pre-training

- To build a foundational "world model" by learning general-purpose representations of language, including grammar, facts, reasoning patterns, and syntax. This is the most computationally intensive and expensive phase.
- **Data:** Massive, unlabeled text corpora scraped from the internet (e.g., web pages, books, code repositories), often spanning trillions of tokens.
- **Methodology: Self-supervised learning.** The model learns by predicting masked parts of the input (Masked Language Modeling, e.g., BERT) or the next token in a sequence (Autoregressive Modeling, e.g., GPT). The Transformer architecture is used due to its superior parallelization and scaling properties.
- **Outcome: A Base Model.** This model possesses broad capabilities but is unrefined. Its outputs are unpredictable and may be biased, toxic, or simply not useful for following specific instructions.

Unsafe Outputs – Alignment Problem

- LLMs may produce
 - Harmful text – unparliamentary language, bias and discrimination
 - Text that can cause direct harm – allowing easy access to dangerous information
- Therefore, LLMs should be trained to produce outputs that align with human preferences and values
- Modern LLMs do so by using SFT and by using human preference directly in model training

Supervised Fine-tuning versus Pre-training

- Objective function
 - Loss computed only for target tokens in SFT, all tokens are targets in pre-training
- Input and Target
 - Instruction + input as input with the target in SFT and only input as input with shifted input as target
- Purpose
 - Pre-training makes good generalist auto-completes but good SFT builds models that can do many unseen tasks
 - SFT can also guide nature of outputs in terms of safety and helpfulness

When we don't have large enough data for SFT

- Freeze the LM and keep some parameters trainable
- Add an external adapter module to adapt model parameters to the task
- Perform Low-rank Adaptation (LoRA)

REWARD MODELING (RM)

- To create a model that can score responses based on human preferences, acting as a proxy for human evaluators.
- **Data:** Human labelers rank multiple model-generated responses to the same prompt from best to worst. These rankings form a preference dataset.
- **Methodology:** A separate model (often a smaller Transformer) is trained on this dataset to predict which response a human would prefer. It learns to output a scalar **reward score**.

Reinforcement Learning (RL) Fine-Tuning

- To optimize the SFT model to generate outputs that maximize the reward score from the Reward Model, thus aligning with human preferences.
- **Methodology:** The **SFT Model** is treated as an RL agent. Its policy is to generate text, and the **Reward Model** provides a reward signal. The **PPO (Proximal Policy Optimization)** algorithm is commonly used to update the model's weights, encouraging it to produce high-reward responses and discouraging low-reward ones. This step requires careful handling to prevent the model from "over-optimizing" and losing its core capabilities.
- **Outcome:** The final **Aligned Model** (e.g., ChatGPT). This model is significantly more helpful, harmless, and honest in its interactions.

Training Of Decoder-only LLMs – Llama 2

- Auto-regressive Pre-training - Train to predict the next token on very large scale corpora (~3 trillion tokens)
- Instruction Fine-tuning/ Supervised Fine-tuning (SFT) - Fine-tune the pretrained model with pairs of (instruction + input, output) with large dataset and then with small high-quality dataset
- Safety / RLHF - Design a reward model based on human feedback and use policy gradient methods with the trained reward model to update LLM parameters so that outputs align with human values

Does doing RLHF and safety tuning mean LLMs will never produce harmful outputs ?

- No! The list of harmful outputs is not exhaustive and very large
- What are the other concerns?
 - Adversarial Robustness – adversaries can force the LLM to produce harmful outputs by attacking the model
 - In our experience, Claude produces harmful outputs the least when compared to models like ChatGPT and Llama

2.4 LLM INFERENCE

- Inference, also known as decoding or serving, is the process of using a trained Large Language Model (LLM) to generate text. While training is a one-time, intensive cost, inference is the repeated, operational cost that defines the user experience.
- Prompts
- Chain of thought prompting

PROMPTS

- Prompts
 - Tell the model what to do in natural language
 - For example, generate a textual summary of this paragraph:
 - Can be as short or long as required
- Prompt Engineering
 - The task of identifying the correct prompt needed to perform a task
 - General rule of thumb be as specific and descriptive as possible
 - Can be manual or automatic (prefix-tuning, paraphrasing etc.)

CHAIN OF THOUGHT PROMPTING

- Get the model to work through the steps of the problem
 - Improves Accuracy: By breaking down complex problems into simpler steps, chain of thought prompting reduces errors and encourages logical coherence.
 - Increases Confidence: Models tend to be more certain when outputs are derived through reasoned pathways.
 - Theoretical Power: Research shows that with sufficiently long chains, Transformers can approximate any computation solvable by polynomial-size circuits, bridging toward Turing-machine-like generality.

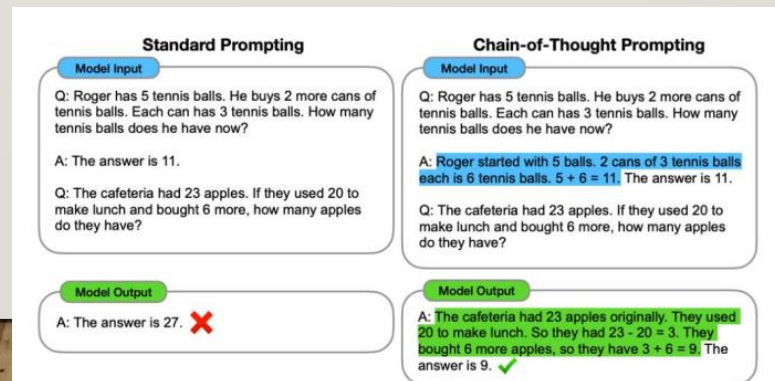


Figure 1: Chain-of-thought prompting enables large language models to tackle complex arithmetic, commonsense, and symbolic reasoning tasks. Chain-of-thought reasoning processes are highlighted.

2.5 EVALUATING LLMS

- Key Evaluation Platforms & Benchmarks

| Name | Type | Maintainer / Origin | Key Focus / Strengths |
|------------------------------------|----------------------|---------------------|--|
| Chatbot Arena (LMSYS Arena) | Platform | LMSYS Organization | Real-world user preference through blind, crowdsourced voting (Elo rating) |
| Open LLM Leaderboard | Platform | Hugging Face | Standardized academic benchmarks for open-access models |
| HELM | Framework & Platform | Stanford University | Holistic, thorough, and reproducible evaluation across many scenarios and ethics |
| OpenCompass | Framework & Platform | Shanghai AI Lab | Comprehensive evaluation supporting English & Chinese, with customizable tools |
| MMLU | Benchmark | Meta & UC Berkeley | Massive multi-task accuracy across 57 academic disciplines |
| GSM8K | Benchmark | OpenAI | Step-by-step mathematical reasoning on grade school problems |
| HumanEval | Benchmark | OpenAI | Functional correctness of code generation (Python) |
| TruthfulQA | Benchmark | | Measuring truthfulness and reducing hallucinations on deceptive questions |

Capability Category

- General Knowledge and Reasoning
- Abstract Reasoning and AGI
- Mathematical Reasoning Ability
- Programming Ability

| Capability Category | Core Evaluation Platform/Benchmark | Platform Features and Evaluation Focus | Typical Model Rankings (For Reference Only) |
|-----------------------------------|--|---|---|
| General Knowledge and Reasoning | MMLU (Massive Multitask Language Understanding) OpenCompass (Si Nan) Hugging Face Open LLM Leaderboard | Covers 57 disciplines; comprehensive evaluation emphasizing Chinese capability; integrates multiple academic benchmarks. | Gemini 1.0 Ultra (90.0%) > GPT-4o (86.4%) > Qwen-72B (77.37%) > Llama 2-70B Qwen-72B base and dialogue models once ranked top three. Qwen-72B (73.6) > Llama 2-70B |
| Abstract Reasoning and AGI | ARC-AGI (Abstract Reasoning Corpus) GPQA (Graduate-Level Q&A) | Measures abstract reasoning for AGI; contains high-difficulty, multidisciplinary science reasoning problems. | Grok 4 Heavy scored over 10% in "v2 Semi Private", nearly doubling second-place Claude Opus 4. Grok 4 (88.9%) |
| Mathematical Reasoning Ability | GSM8K (Grade School Math Word Problems) AIME (American Invitational Mathematics Examination) | Evaluates multi-step math reasoning; assesses competition-level problem-solving. | Qwen-72B (70.43%) > Llama 2-70B DeepSeek-R1 and Tencent Hunyuan T1 tied for first with zero errors in 2025 Gaokao math; Grok 4 Heavy achieved 100% in AIME25. |
| Programming Ability | HumanEval LiveCodeBench SWE-bench | Evaluates Python code generation (functional correctness); dynamic assessment with fresh problems; tests real-world software engineering tasks. | Claude 3.7 Sonnet (92.1%) > GPT-4.1 (89.3%) > Qwen2.5-Max (88.5%) > DeepSeek-R1 (84.9%) Qwen2.5-Max excels in code generation, nearing Claude 4 Opus and leading open-source models. Claude 4 Opus (80.2%) > Gemini 2.5 Pro (70.1%) > Qwen2.5-Max (72.3%) > DeepSeek-R1 (69.7%) |
| Practical Music Intelligent Agent | Suno Kunlun Wanwei Mureka Series Free-scale "Yin Chao" | Autoregressive music generation with full-song support; copyright issues exist. Uses CoT for global structure planning. AR + NAR architecture with multimodal representation; high-fidelity music generation in 10+ languages and 20+ styles. Rich orchestration and industrial production quality; cross-modal input support. | Suno series faces copyright disputes. Mureka: 50% faster generation, auditory score 6.93 (once exceeded Suno V4). Yin Chao: Professional-grade music generation from text/image/video input. |

Conclusion

- **Diversified Evaluation Dimensions:** Assessing large models no longer relies on a single metric but requires a comprehensive evaluation of general knowledge, specialized reasoning (e.g., mathematics, programming), abstract thinking, and multimodal capabilities.
- **Strong Rise of Open-Source Models:** Open-source models like **DeepSeek R1** and the **Qwen** series have demonstrated outstanding performance in various evaluations, rivaling or even surpassing closed-source models in specific areas, thereby driving technological popularization and application.
- **Abstract Reasoning Remains a Challenge:** Benchmarks like **ARC-AGI** indicate that abstract reasoning remains a significant challenge for current large models and a key bottleneck toward AGI. While top models are improving, a considerable gap with human performance persists.
- **Balancing Practicality and Cost:** When selecting a model, besides ranking, it's essential to consider factors like **API cost, response speed, ecosystem support** (e.g., the customizability of open-source models), and suitability for specific vertical scenarios.

2.6 OPEN CHALLENGES

- **New Capabilities**
 - Multimodal
 - Multi-lingual
 - More Complex Tasks
- **Performance**
 - Reduce Hallucinations
 - Improve Alignment with Human Preference
 - Increase Context Length Efficiently
 - Improve Data, Training Strategy, and Model Architecture
- **Efficiency**
 - Computational cost, time, and money
 - Compute architecture – GPU/ TPU/ HPU
- **Safety**
 - Reduce Harm
 - Improve Adversarial Robustness
 - Privacy Concerns
- **Interpretability**
 - Why do LLMs do what they do?

PART 03

PATHWAYS FOR LLMS TO ENABLE THE SDGS

PATHWAYS FOR LLMs TO ENABLE THE SDGs

- **SDG Research Priorities**
- **SDG Stakeholder Analysis**
- **Large Model Technologies Enabling SDG Research**

3.1 SDG RESEARCH PRIORITIES



Economic Dimension

Goals focused on economic growth, poverty reduction, and sustainable consumption



Social Dimension

Goals focused on quality education, health, and peaceful inclusive societies



Environmental Dimension

Goals focused on climate action, sustainable cities, and biodiversity protection

💡 Key Research Priorities

☁️ Climate Action (SDG 13)

🎓 Quality Education (SDG 4)

💚 Health and Well-being (SDG 3)

🏙️ Sustainable Cities (SDG 11)

Priority Area: Climate Action (SDG 13)

 Taking urgent action to address climate change

Climate action focuses on addressing extreme weather events, glacier melting, and water resource distribution challenges through AI-driven solutions.



Climate Monitoring

- Precise prediction of glacier melting risks
- Analysis of satellite remote sensing and ground observations
- Accurate monitoring of water resource changes



Climate Mitigation

- AI optimization of renewable energy management
- Prediction of solar and wind power generation
- Smart grid optimization to reduce energy waste



Climate Prediction

- Integration of AI with climate models for better projections
- Downscaling global climate data to local actionable insights
- Early detection of climate tipping points



Climate Adaptation

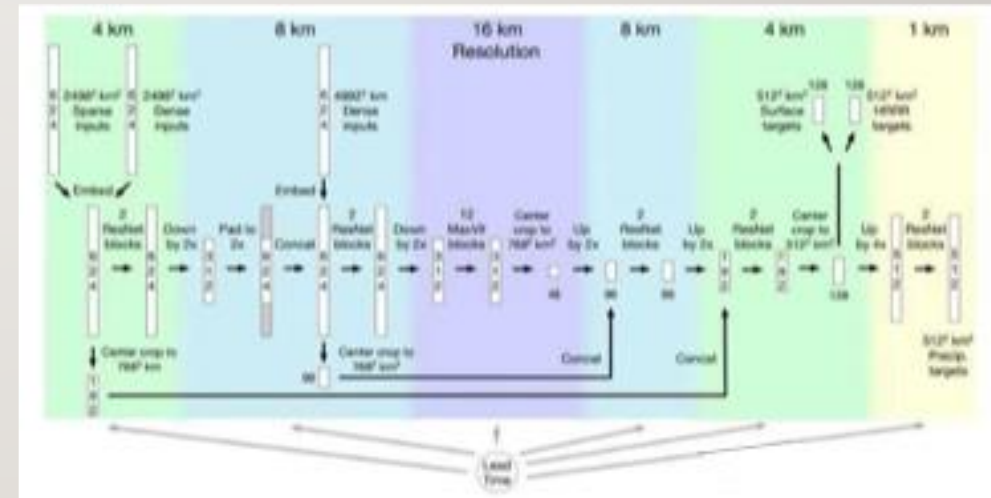
- Pollution source analysis and reduction strategies
- Analysis of pollution distribution and diffusions pathways
- Optimization of resource allocation for climate resilience

AI + CLIMATE

- Traditional numerical weather prediction
 - employed by most meteorological agencies, relies on physical models and high-performance computing to solve partial differential equations, yet it is computationally intensive and susceptible to errors from parameterization.
- AI-based forecasting
 - uses deep neural networks trained on reanalysis data to model atmospheric processes, enabling rapid predictions with high spatiotemporal resolution directly from observations.

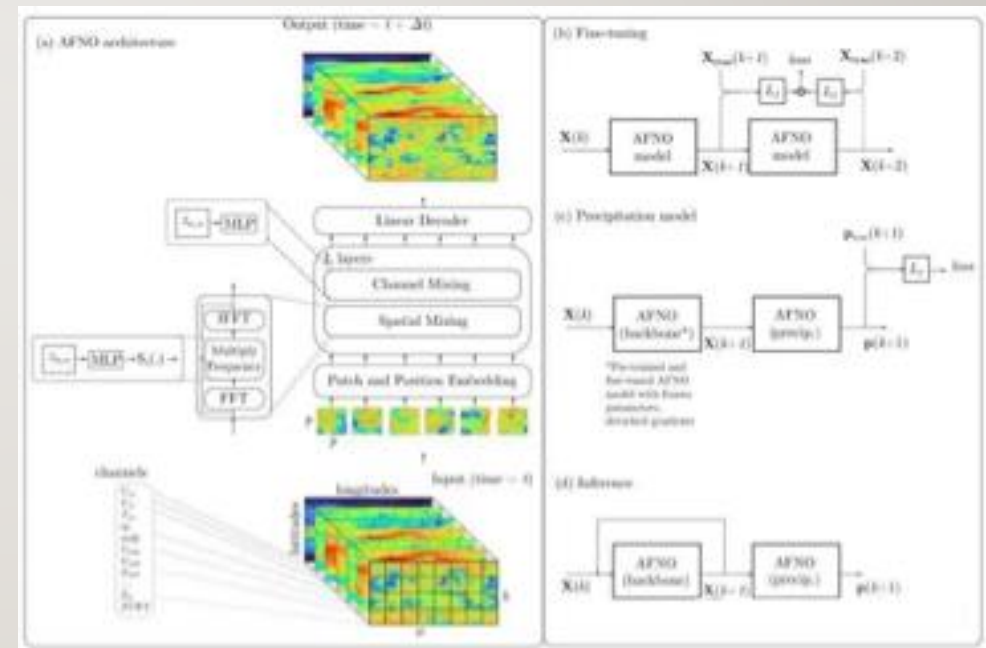
LARGE AI WEATHER FORECAST MODEL

- **MetNet series** - Google
 - MetNet(2020), MetNet-2(2021), MetNet-3(2023, with DeepMind)
 - Use a purely data-driven approach to achieve high-resolution precipitation and weather forecasts
 - MetNet-3 surpassed traditional numerical weather prediction accuracy by incorporating a U-Net backbone with Transformer-based modules, extending forecast capability to 24 hours
 - Despite its operational use in Google Weather, the series remains limited in physical constraints and interpretability.



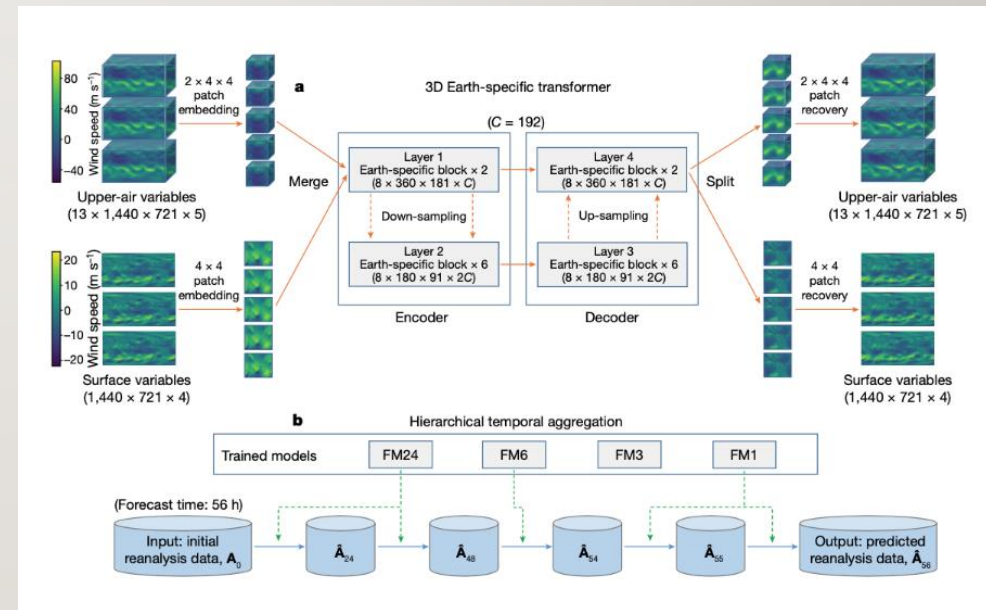
LARGE AI WEATHER FORECAST MODEL

- **Fourcastnet** – NVIDIA, LBNL, University of Michigan, Ann Arbor, Rice University, etc. (2022)
 - Utilizing Adaptive Fourier Neural Operators (AFNO) to achieve highly efficient, global weather forecasting at 0.25° resolution.
 - It generates a one-week forecast in just two seconds, 45,000 times faster than ECMWF's IFS
 - Employs a "pre-training and fine-tuning" paradigm, achieving end-to-end downstream task prediction with minimal parameters.
 - Although it did not surpass the absolute accuracy of the most advanced operational numerical models, FourCastNet established a new benchmark for speed and resolution in AI-based weather prediction.



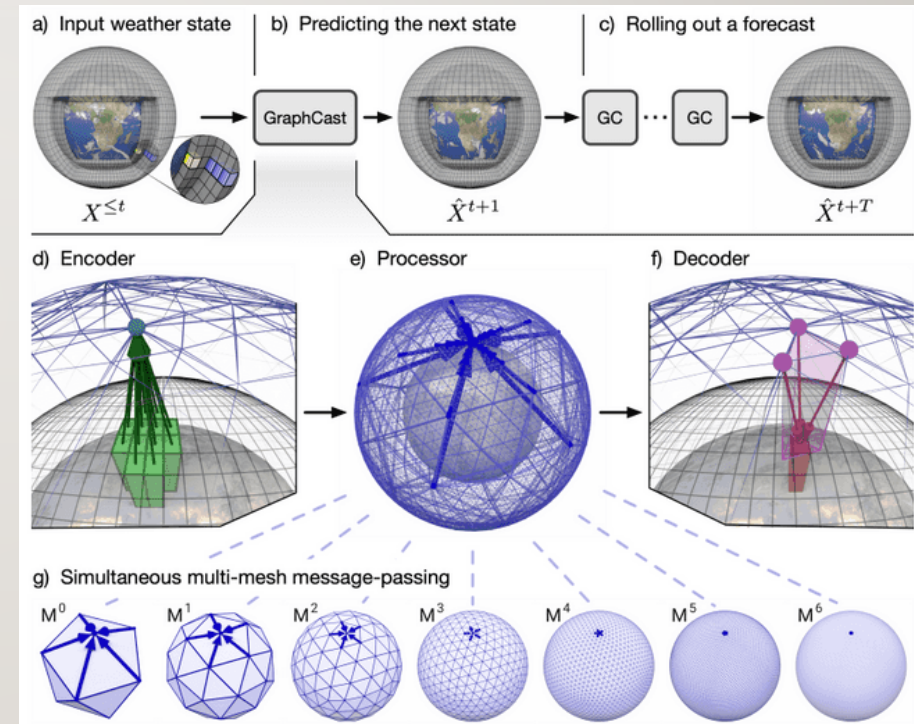
LARGE AI WEATHER FORECAST MODEL

- **Pangu – Huawei (2022)**
 - A purely data-driven model that surpassed traditional NWP in accuracy for the first time while offering a 10,000-fold speedup.
 - Providing high-precision (0.25°) weather forecasts with a validity period ranging from 1 hour to 7 days.
 - Trained on 39 years (1979-2017) of ERA5 data, it achieves competitive inference speed and marks a significant breakthrough in operational AI-based weather forecasting.



LARGE AI WEATHER FORECAST MODEL

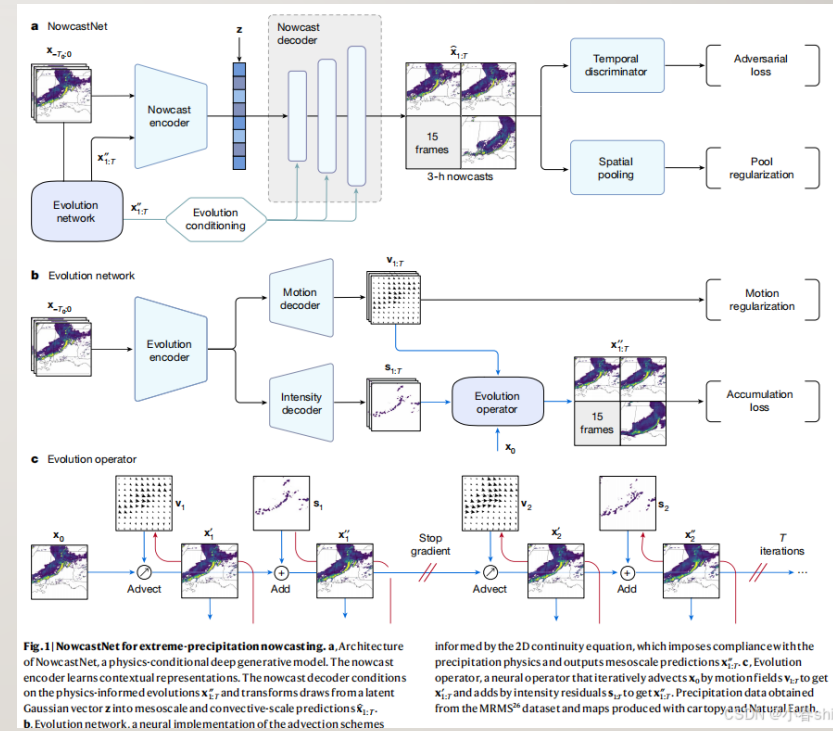
- **Graphcast** – DeepMind & Google (2022)
 - Autoregressive weather forecasting model based on graph neural networks (GNN)
 - Delivers highly accurate 10-day global predictions at 0.25° resolution in under 60 seconds on a single TPU v4.
 - It outperforms the leading AI-based model, Pangu-Weather, in 99.2% of 252 variables and surpasses ECMWF's HRES forecasts in 90% of 2,760 metrics.
 - Trained on four decades of ERA5 reanalysis data, the model employs a multi-grid architecture to capture long-range spatial interactions.



LARGE AI WEATHER FORECAST MODEL

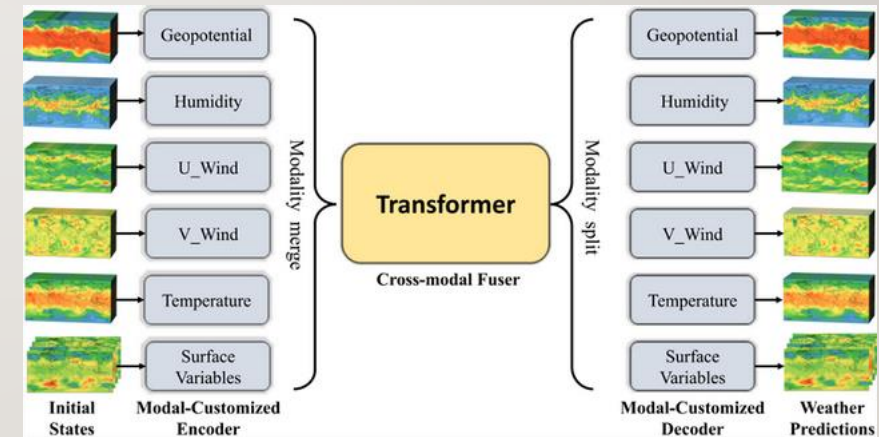
- **NowcastNet** – THU, NMC, NMIC (2023)

- Address the significant gap in large AI models for predicting extreme precipitation events
- Extending prediction lead time to 3 hours with high spatiotemporal resolution (20 km, 10 min).
- Utilizes six years of radar observation data, integrating both raw and predicted radar inputs through its encoder.
- Incorporates physical constraints via neural evolution operators to enable end-to-end modeling of precipitation physics, while a probabilistic generative model captures fine-scale details based on mesoscale predictions
- Deployed operationally on SWAN 3.0



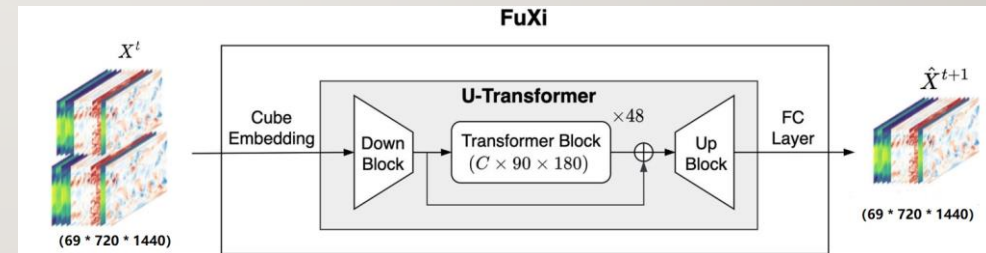
LARGE AI WEATHER FORECAST MODEL

- **FengWu** – USTC, SJTU, NUIST, IAP CAS, SMS (2023)
 - High-resolution (0.25°) 10-day forecasts in under 30 seconds.
 - Employs a multi-modal neural network and multi-task learning framework to capture interactions among atmospheric variables, optimized via a replay buffer strategy to efficiently minimize autoregressive training errors.
 - Extends effective prediction validity to 10.75 days, demonstrating superior computational efficiency compared to methods like GraphCast.



LARGE AI WEATHER FORECAST MODEL

- **Fuxi** – Fudan University (2023)
 - 4.5 billion parameters, based on a U-Transformer architecture that generates high-resolution (0.25°) 15-day forecasts through a cascaded structure and multi-time-step loss optimization to minimize error accumulation.
 - It extends deep learning-based weather prediction to 15 days, outperforming ECMWF's deterministic HRES system in 10-day forecasts at 6-hour intervals.
 - Fuxi matches the performance of ECMWF's ensemble mean forecast at 15 days, demonstrating state-of-the-art accuracy in long-range prediction.



KEY CHALLENGES OF CURRENT AI WEATHER MODELS

- **Interpretability and Physical Consistency:**
 - The black-box nature of deep learning models limits understanding of their decision-making processes and physical basis, requiring greater integration of physical constraints and hybrid scientific paradigms.
- **Computational Efficiency and Generalization:**
 - While inference is highly efficient, training demands enormous computational resources and massive datasets, creating a trade-off between training costs and model generalization capability.
- **Extreme Event Prediction:**
 - Models tend to produce over-smoothed results and perform poorly in forecasting rare and extreme weather events due to statistical biases and data limitations.

Priority Area: : Quality Education (SDG 4)

 "Ensure inclusive and quality education"

AI technologies are transforming education by providing new pathways to achieve SDG 4: Quality Education. These technologies address barriers to quality education and contribute to more equitable learning opportunities.



Personalized Learning

- Adapts to individual learning pace and style
- Recommends content based on progress
- Creates customized learning paths



Intelligent Tutoring

- Provides immediate feedback
- Offers personalized guidance
- Bridges resource gaps



Educational Management

- Analyzes educational data
- Optimizes curriculum design
- Improves resource allocation



AI in education helps address barriers to quality education, promoting equitable learning opportunities and contributing to SDG 4 achievement.

CHALLENGES AND CONSIDERATIONS

While AI presents significant opportunities, its transformation also brings challenges:

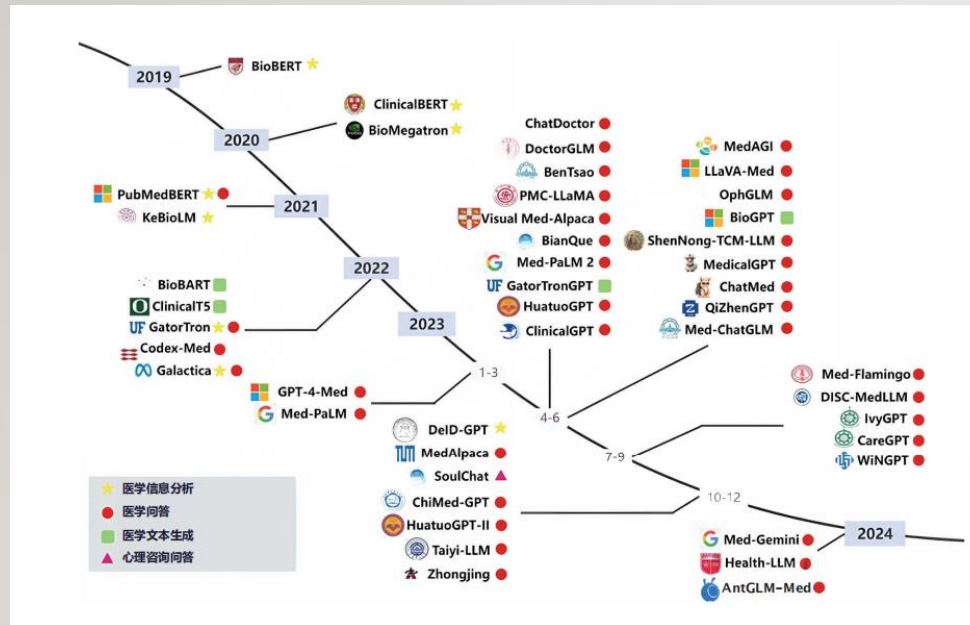
- **Digital Divide:** May exacerbate educational inequality.
- **Data Privacy:** Protecting students' sensitive data is crucial.
- **Emotional and Social Development:** Education involves not only knowledge transfer but also emotional support and interpersonal skills, which AI struggles to replace.
- **Academic Integrity:** Students might use AI tools to complete assignments, raising new challenges in defining and preventing cheating.

Priority Area: Health and Well-being (SDG 3)

- Disease Diagnosis & Treatment
 - Enhanced medical imaging analysis for earlier detection
 - AI-assisted identification of early disease indicators
 - Personalized treatment plan optimization
- Drug Development
 - Molecular interaction simulation to identify potential drug targets
 - Drug efficacy prediction to optimize clinical trial outcomes
 - Toxicity prediction to reduce adverse drug reactions
- Public Health Management
 - Epidemic data analysis and trend prediction
 - Early warning systems for disease outbreaks
 - Resource allocation optimization for vaccination and treatment

AI is revolutionizing healthcare and public health, offering new approaches to improve global health outcomes through earlier detection, more effective treatments, and better management of health systems.

THE EVOLUTION FROM UNIMODAL TOOLS TO MULTIMODAL AGENTS



- Multimodal Integration
 - Breaking through the limitations of early vertical models to achieve collaborative analysis of text, imaging, and genetic sequences.
- Restructuring Diagnosis and Treatment
 - Deep integration of clinical knowledge bases and patient data to empower precision medicine.
- Swarm Intelligence
 - IoT and 5G enable cross-device collaboration, forming a full-process intelligent ecosystem within hospitals.

AI APPLICATIONS IN MEDICAL & HEALTH

- **Ant Medical's “Top Doctor AI Agent”** - Alibaba
 - Integrates top physicians' professional knowledge and distinctive vocal profiles to achieve high-fidelity replication of diagnostic and treatment workflows.
 - Delivers 24/7 online specialty consultations on specific diseases, expanding access to expert-level medical advice for broader communities.
 - Enables scalable and equitable distribution of high-quality medical resources through digital replication.
 - Extends expert diagnostic capabilities to primary care institutions, significantly improving the quality and efficiency of grassroots healthcare services.



AI APPLICATIONS IN MEDICAL & HEALTH

- **West China Hosipital**
 - **Ruibing Agent:** This medical AI agent specializes in the field of gastroenterology, offering targeted support in digestive health diagnosis and treatment.
 - **Yizhi Dr.:** Provides personalized medical consultation based on patient-uploaded health data, enabling end-to-end tracking and management—from disease prevention and diagnosis to treatment and recovery—and delivering tailored whole-cycle health management plans.
 - **Lunjie Scholar:** A computer-based tool designed to assist medical professionals with research support, offering intelligent interpretation and analysis of academic papers for doctors and medical students.



AI APPLICATIONS IN MEDICAL & HEALTH

- **Ruijin Hospital**

- Intelligent Virtual Diagnosis and Treatment System Based on Virtual Standardized Patients.
- Employs multi-sensory interactive feedback technology to enable end-to-end training coverage - from diagnostic reasoning to practical procedures such as needle insertion.
- Overcomes the limitations of traditional standardized patients by dynamically simulating drug metabolism and pathological responses.






Priority Area: Sustainable Cities (SDG 11)

 Building Sustainable Urban Futures






Smart City Planning

-  Analyzes urban big data including population flow, energy consumption, and environmental quality
-  Provides decision support for more scientific and sustainable urban development
-  Enhances urban planning through data-driven insights






Intelligent Transportation

-  Optimizes traffic signal control and predicts congestion patterns
-  Reduces average commute time and carbon emissions
-  Supports sustainable mobility solutions and infrastructure planning



Resource Optimization

-  Optimizes water resource allocation through rainfall prediction and demand forecasting
-  Improves waste management through image recognition and data analysis
-  Enhances resource utilization efficiency across urban systems

AI-Driven Urban Planning Process



Data Collection



AI Processing



Pattern Recognition



Decision Support



Urban Planning

INTELLIGENT TRANSPORTATION SYSTEMS

Key Benefits



Reduced Commute Times

Real-time traffic prediction and signal optimization reduce congestion and travel time.



Lower Carbon Emissions

Optimized traffic flow reduces idle time and unnecessary routes, decreasing environmental impact.



Data-Driven Decisions

Analysis of historical and real-time traffic patterns provides insights for infrastructure planning.



Improved User Experience

Real-time information and personalized route planning enhances commuter satisfaction.

AI Applications in Transportation



Intelligent Traffic Signal Control

AI algorithms analyze real-time traffic conditions to optimize signal timing, reducing congestion at key intersections.



Predictive Traffic Modeling

Machine learning models forecast traffic patterns, allowing proactive management of potential congestion before it occurs.



Demand Responsive Transit

AI systems analyze passenger demand patterns to optimize public transit routes and schedules, improving service efficiency.



Infrastructure Planning

AI-driven analysis of transportation data informs decisions about road construction, capacity expansion, and resource allocation.

3.2 SDG STAKEHOLDER ANALYSIS

In the implementation of Sustainable Development Goals (SDGs), different stakeholders play unique roles with distinct characteristics and needs. Understanding these stakeholders is crucial for effective SDG implementation and for leveraging AI technologies appropriately.



Government Agencies

Policy makers, funders, and monitors



Private Sector

Innovation and resource providers



Non-Governmental Organizations

Advocacy and implementation



Academic Institutions

Research and knowledge transfer



Stakeholder Collaboration

Coordinated action and synergy

Key Questions for Analysis:

- ✓ How do different stakeholders contribute to SDG implementation?
- ✓ How can AI technologies address stakeholder-specific needs?
- ✓ What are the unique characteristics of each stakeholder group?
- ✓ What barriers prevent effective stakeholder engagement?

THE STAKEHOLDER ECOSYSTEM IN SUSTAINABLE DEVELOPMENT

- The implementation of Sustainable Development Goals (SDGs) requires coordinated action from a diverse array of stakeholders. As of 2025, 190 of the UN's 193 member countries have participated in the Voluntary National Review (VNR) process, submitting sustainable development plans and priorities.



GOVERNMENT AGENCIES: POLICY AND COORDINATION

Government agencies play a core role in SDG implementation through strategic planning, policy development, funding allocation, and progress monitoring.



Policy Development

Formulate national policies that align with SDGs through strategic planning and voluntary national reviews (VNRs). 190 of 193 UN member countries have participated in the VNR process.



Resource Provision

Allocate budget resources and funding mechanisms to support SDG implementation at national and local levels, ensuring financial sustainability.



Action Coordination

Coordinate actions across different government departments, stakeholders, and geographic levels to ensure integrated and coherent implementation.



Progress Monitoring

Track and evaluate SDG implementation through national monitoring frameworks and reporting mechanisms, using data to inform policy adjustments.



AI-Enhanced Government Functions



Data-Driven Policy

Using AI for evidence-based policy formulation



Service Optimization

Improving public services like water management



Environmental Governance

Enhancing environmental monitoring and management

PRIVATE SECTOR: INNOVATION AND RESOURCES

Private businesses are key drivers of SDG implementation, contributing through ESG integration, innovation, and resource mobilization.



ESG Integration

Companies incorporate Environmental, Social, and Governance principles into their operations and strategies, directly contributing to multiple SDGs.



Targeting SDGs

Companies strategically align their ESG goals with specific SDGs

Responsible Consumption

SDG 12

Inclusive Recruitment

SDG 10

Clean Energy Solutions

SDG 7

Precision Agriculture

SDG 2



AI-Driven Innovation

Businesses leverage AI for sustainable operations:

Energy optimization (like Google DeepMind's 40% data center efficiency improvement)

Supply chain optimization

Development of sustainable products

NON-GOVERNMENTAL ORGANIZATIONS: ADVOCACY AND IMPLEMENTATION

Grassroots Work



NGOs implement programs at the local level, working directly with communities to address sustainable development challenges. They often have deeper community connections and understanding of local needs compared to larger institutions.

- ✓ Community mobilization
- ✓ Local resource distribution
- ✓ Grassroots innovation

Policy Advocacy



NGOs advocate for policy changes at local, national, and international levels to create enabling environments for sustainable development. They use their expertise and networks to influence decision-making processes.

- ✓ Advocacy campaigns
- ✓ Policy research
- ✓ Stakeholder engagement

Service Provision



NGOs provide critical services that address specific sustainable development challenges, filling gaps in service delivery left by governments and markets. They often focus on the most vulnerable populations.

- ✓ Direct service delivery
- ✓ Targeted interventions
- ✓ Support for vulnerable groups

Progress Monitoring



NGOs monitor SDG implementation at local and national levels, evaluating progress toward sustainable development goals. They provide independent assessments and highlight challenges and opportunities.

- ✓ Independent monitoring
- ✓ Gap analysis
- ✓ Advocacy for accountability

? NGOs bring unique value to SDG implementation through their expertise, networks, and mobilization capabilities, often working in partnership with other stakeholders to address complex sustainable development challenges.

AI FOR SCIENCE: TRANSFORMING RESEARCH PARADIGMS

AI is driving a paradigm shift in scientific research, enabling new approaches to complex problems across disciplines.



Multimodal Data Mining

Large models process diverse data types simultaneously, enabling more comprehensive insights than traditional methods.



Holistic Analysis

AI systems analyze research problems as interconnected systems rather than isolated components.



Cross-Disciplinary Integration

Bridges traditional disciplinary boundaries, allowing for more comprehensive understanding of complex problems.



Innovative Research Directions

Opening new research avenues in biomedicine, meteorology, materials, life simulation, and energy fields.

AI-Driven Research Transformation Across Fields



Biomedicine



Meteorology



Material Discovery



Life Simulation



Energy Research



Computer Science



Chemistry



Environmental Science

AI4S is enabling a new era of scientific discovery through data-driven insights

STAKEHOLDER COLLABORATION

Effective multi-stakeholder partnerships are essential for SDG implementation.

Key Frameworks for Multi-Stakeholder Partnerships

- **Inclusive Governance**
 - Ensuring diverse participation
- **Public-Private Partnerships**
 - Collaboration for sustainable development
- **Academic-Industry Engagement**
 - Translating research into practice



3.3 LARGE MODEL TECHNOLOGIES ENABLING SDG RESEARCH

- Chat
 - Yuanbao: <https://yuanbao.tencent.com/>, Tencent
 - Kimi: <https://www.kimi.com/>, Moonshot AI
- Science
 - ScienceOne: <https://scienceone.ia.ac.cn/>, The Institute of Automation of the Chinese Academy of Sciences (CASIA)
- Lingxi SDG Models (*will be published on Sep 6th, 2025*)
 - Knowledge Q&A
 - Literature Survey
 - Indicator Monitor
 - SDG Report Writing

AI FOR SDG RESEARCH

**灵息·SDG大模型**
LingXi-SDG

Home | SDG AI Agent | About | English

LingXi · SDG

Dedicated AI system for Sustainable Development

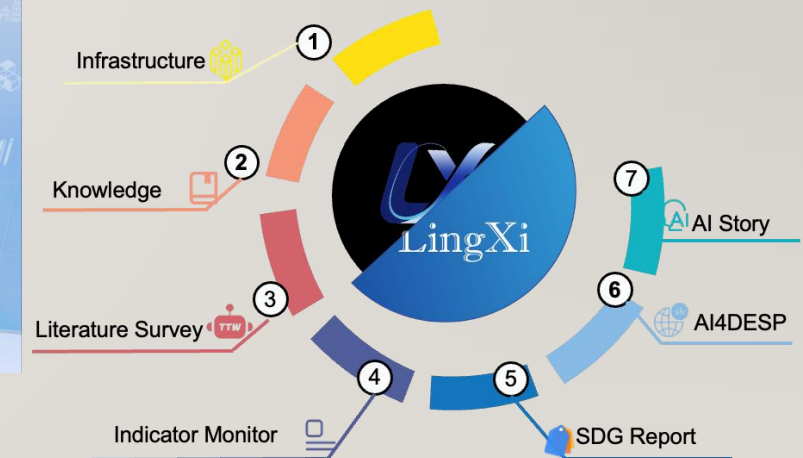
Deeply integrate domain knowledge to enhance multimodal understanding, causal reasoning, and temporal analysis capabilities, empowering decision-makers with science-driven, high-efficiency sustainable development solutions



Core services

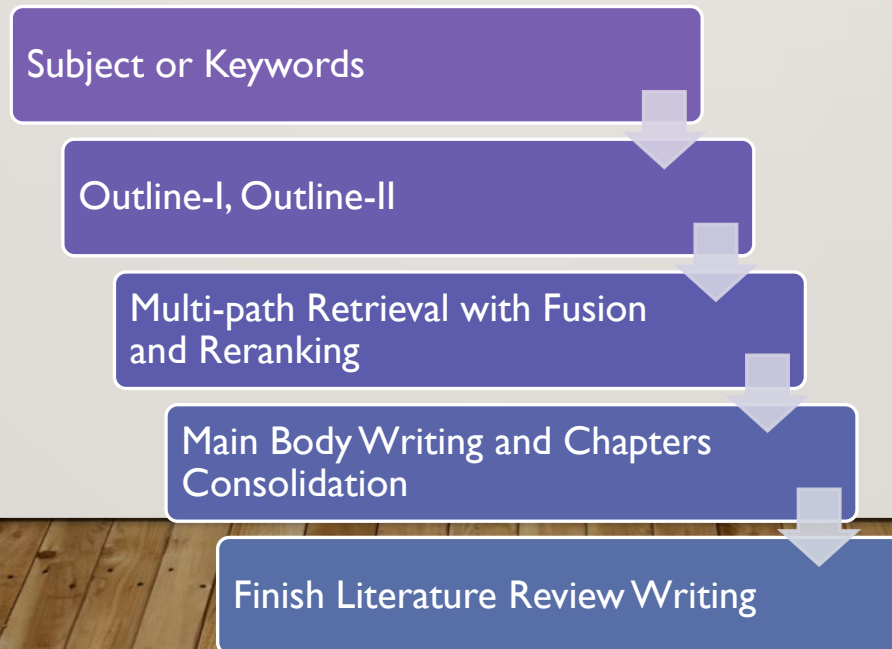
- SDG Report Assistant**
Leveraging the summarization and inductive reasoning capabilities of large language models (LLMs) to compile expert-level multilingual progress reports on SDG indicators at global, regional, and national scales
- SDG Literature Survey**
Producing high-level review reports on SDG-related research advancements
- SDG Indicator Monitor**
Integrating global multidimensional SDG data to develop an SDG data analytics agent capable of query resolution, in-depth analysis, and automated visualization report generation
- AI4DESP**
Build AI-Ready multimodal datasets, AI agents and AI Viewer to empower precise perception, intelligent decision-making, and sustainable development
- AI STORY**
Build an SDG-oriented intelligent storytelling platform that integrates data acquisition, analysis, story generation and visualization to promote understanding and implementation of the global Sustainable Development Goals

[Literature Survey](#) | [Indicator Monitor](#) | [Analysis Report](#) | [AI4DESP](#) | [AI Story](#)



LITERATURE SURVEY

- This agent service integrates three core modules: a database retrieval system, a generation workflow system, and a literature review quality evaluation system.
- It supports natural language interaction and intelligently generates high-quality research reviews.



LITERATURE SURVEY

Tool name: generate_survey, parameter: {"topic": "A Survey of the Current Status Analysis of SDG 15", "survey_len": 4000}



Tool Execution Information

Working on the summary outline.



Tool Execution Information

Working on the Tier-1 outline.



Tool Execution Information

Working on the Tier-2 outline.



Tool Execution Information

Organizing the outline content.



Tool Execution Information

Currently composing the literature review body.



A Comprehensive Survey of the Current Status Analysis of SDG 15: Life on Land

1 Overview of SDG 15 and Its Global Significance

1.1 Introduction to SDG 15: Objectives and Scope

SDG 15, titled "Life on Land," is a critical component of the United Nations' 2030 Agenda for Sustainable Development. It aims to protect, restore, and promote the sustainable use of terrestrial ecosystems, halt deforestation, and combat desertification, while also safeguarding biodiversity and ensuring the sustainable management of forests [1]. The goal recognizes that healthy terrestrial ecosystems are essential for sustaining life, providing ecosystem services such as food production, water filtration, climate regulation, and soil formation. SDG 15 includes a range of specific targets and indicators, such as increasing forest cover, preventing species extinction, and promoting fair access to genetic resources, all of which underscore its comprehensive scope and ambition [1].

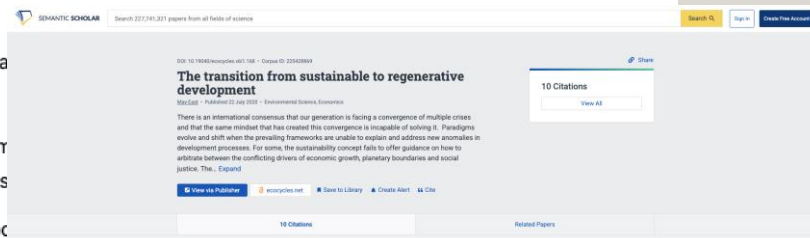
Furthermore, SDG 15 plays a crucial role in advancing the transition from sustainable to regenerative development, which aims to restore ecological balance rather than merely sustaining current depleted conditions [6]. This paradigm shift is essential for remaining within planetary boundaries, particularly regarding land use, biodiversity loss, and freshwater use. By promoting regenerative land-use practices, SDG 15 contributes to the broader objective of ensuring that economic growth does not come at the expense of ecological collapse. As such, SDG 15 is not an isolated environmental goal but a cornerstone of the 2030 Agenda's integrated vision for a just, equitable, and ecologically resilient world.

1.3 Challenges in Aligning Economic Growth with Environmental Sustainability

The alignment of economic growth with environmental sustainability represents a formidable

References

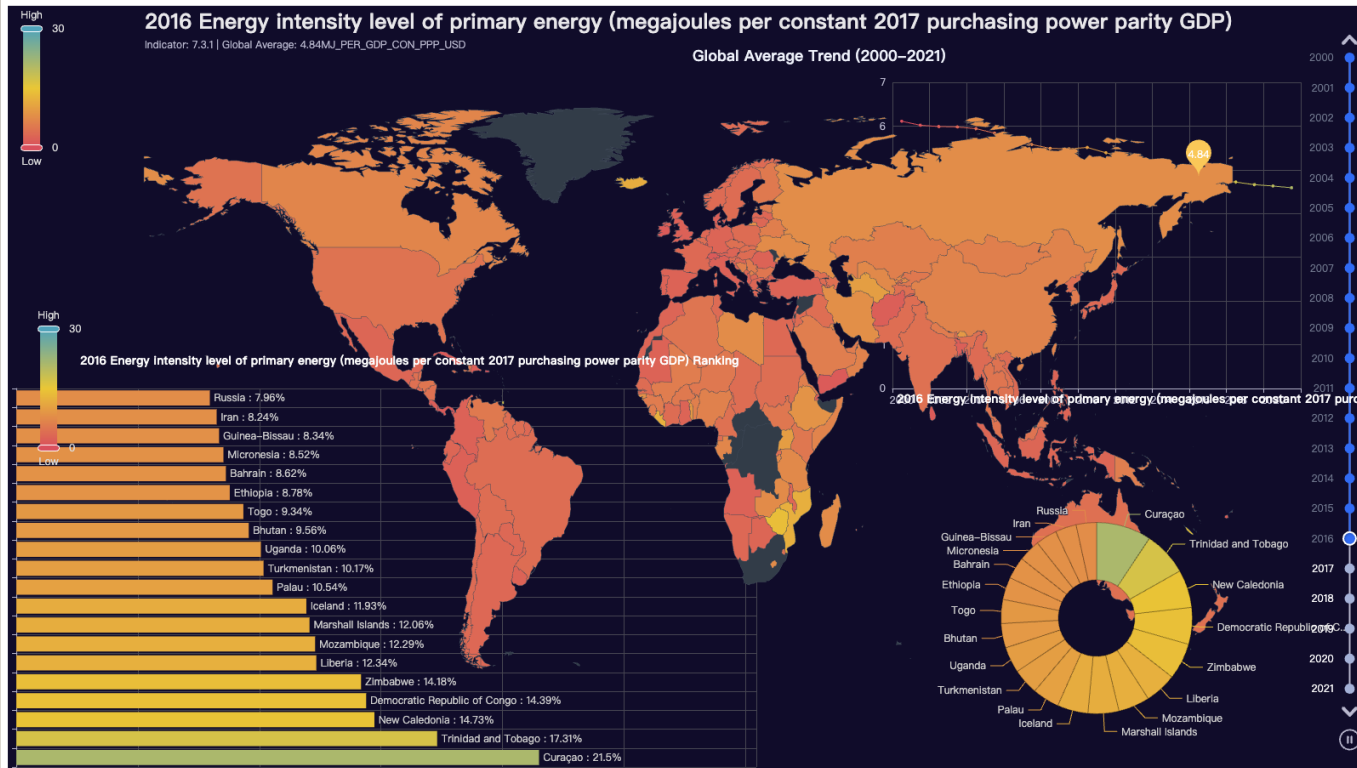
- [1] SDGS, INNOVATION AND IP LICENSING,Gopakumar G. Nair,2024-04-28
- [2] An integrated framework for sustainable development goals,Griggs,2014
- [3] Unravelling the complexity in achieving the 17 sustainable-development goals,Fu, B,2019
- [4] Towards a Political Education Through Environmental Issues,Slimani, Melki,2021-05-28
- [5] Environmental Analysis and the Dual Grand Challenge of COVID-19 and Sustainable Development,E. Psillakis,2021-08-24
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- [7] Linking economic growth pathways and environmental sustainability by understanding development as alternate social-ecological regimes,Cumming,2018
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- [10] Ecological resource availability: a method Desing;G. Braun;R. Hischier,2020-10-06,Citation Num:16



INDICATOR MONITOR

- **Data source:**
 - <https://unstats.un.org/sdgs/dataportal/database>
- **Global-scale**
 - Conducts comparative analysis of long-term time-series data for each SDG indicator.
 - Visualizes the results on a global map.
 - Generates concise analytical reports.
- **National-scale**
 - Performs analysis and visualization of long-term time-series data for each SDG indicator within individual countries.
 - Produces brief analytical reports.

INDICATOR MONITOR



1. Data Source and Methodology

Data Source and Methodology

Data Source: The data provided is sourced from the SDG (Sustainable Development Goals) database, specifically focusing on Indicator 7.3.1: "Energy intensity level of primary energy (megajoules per constant 2017 purchasing power parity GDP)".

Time Range: The dataset covers the period from 2000 to 2021.

Coverage: Global (multiple countries and regions)

Global Overview

Provide a global overview of this indicator:

- Global Average Level/Overall Trends:** The global average energy intensity in 2000 was approximately 6.11 MJ per constant 2017 PPP GDP. This value slightly decreased over the years, reflecting a gradual improvement in energy efficiency worldwide.
- Data Coverage:** The dataset includes data for 227 countries and regions.
- Global Overall Performance Assessment:** There has been a noticeable variation across different regions, with some showing significant improvements while others lag behind.

2. Detailed Analysis

Summary of Query Content and Main Findings

The query focuses on SDG indicator 7.3.1, which measures the energy intensity level of primary energy consumption relative to economic output. This indicator is crucial for assessing progress towards sustainable energy use and efficiency.

INDICATOR MONITOR

图表分析

中国灾害死亡与失踪人数对比 (2015-2022)

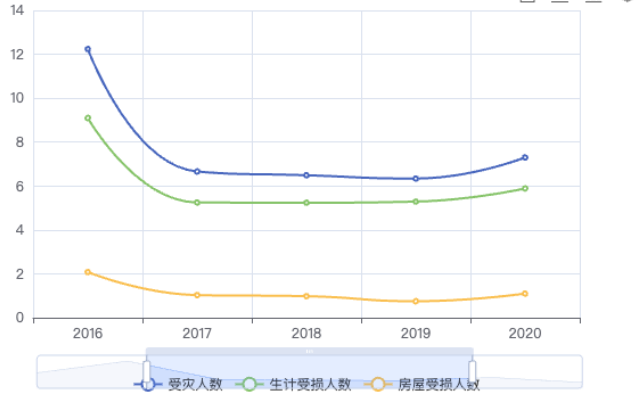
单位: 人



该图表展示了每年受灾害影响的人数变化趋势。从图中可以看出，2016年人数最多，之后逐年减少，直到2020年有所反弹，2022年再次下降。

中国灾害大规模人员影响趋势 (2015-2022)

单位: 百万人



此图表显示了每10万人中直接受灾害影响的人数。总体趋势与受灾害影响的总人数一致，2016年为最高点，之后逐渐减少。

异常值解释

2016年的异常高峰可能是由于当年发生的大规模自然灾害，如洪水、台风等，这些事件导致了大量人口受到影响。

未来情景讨论

基于当前趋势，如果防灾减灾措施继续加强，预计未来几年受灾害影响的人数将继续保持下降趋势。然而，气候变化带来的不确定性可能增加极端天气事件的发生频率，因此仍需警惕。

总结和政策建议

综上所述，虽然近年来中国在防灾减灾方面取得了显著成效，但仍需持续努力。建议：

1. 加强基础设施建设：提升房屋和公共设施的抗灾能力。
2. 完善预警系统：提高灾害预警的准确性和及时性。
3. 普及防灾知识：增强公众的防灾意识和自救能力。
4. 推动国际合作：与其他国家分享经验和技術，共同应对全球气候变化挑战。

通过以上措施，可以进一步降低灾害对人类社会的影响，实现可持续发展目标。

SDG REPORT WRITING

- **Interactive User Engagement:** Operates through user interaction.
- **Bilingual Report Generation:** Automatically produces reports in Chinese and English.
- **Comprehensive SDG Coverage:** Addresses all 17 Sustainable Development Goals (SDGs).
- **Professional Content Integration:** Utilizes expert knowledge, structured data, and graphical representations.
- **Analytical Reasoning:** Employs logical analysis to interpret progress and trends.
- **Visual-Textual Combination:** Delivers outputs that integrate both text and visuals for clarity.

SDG REPORT WRITING

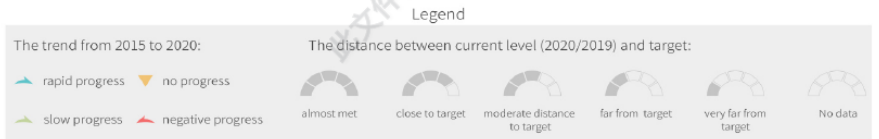
Target

Sustainable Development Goal 5 (SDG 5) aims to achieve gender equality and empower all women and girls, recognizing that gender equality is fundamental to sustainable development and a prosperous, inclusive society. As articulated in the United Nations 2030 Agenda for Sustainable Development, SDG 5 strives to eliminate all forms of discrimination and violence against women and girls, ensure equal opportunities for leadership, and guarantee universal access to sexual and reproductive health and reproductive rights.

The main targets under SDG 5 encompass several critical objectives:

1. End all forms of discrimination against women and girls everywhere (Target 5.1).
2. Eliminate all forms of violence against women and girls, including trafficking and sexual and other types of exploitation (Target 5.2).
3. Eliminate harmful practices, such as child, early, and forced marriage and female genital mutilation (Target 5.3).
4. Recognize and value unpaid care and domestic work and promote shared responsibility within the household (Target 5.4).
5. Ensure women's full and effective participation and equal opportunities for leadership at all levels of decision-making in political, economic, and public life (Target 5.5).
6. Ensure universal access to sexual and reproductive health and reproductive rights as agreed in accordance with international frameworks (Target 5.6).

Visual analytics dashboards, built upon integrated SDG 5 indicator data, reinforce the importance of both regional leadership and context-sensitive strategies. Countries exhibiting best practices—most notably those in Northern and Western Europe and selected low- and middle-income countries that have pioneered innovative reforms—demonstrate that progress is achievable given sustained political commitment, resource allocation, and robust monitoring systems.



Discussion and Outlook

The trajectory toward achieving Sustainable Development Goal 5 (SDG 5)—gender equality and empowerment of all women and girls—demonstrates measurable global progress, yet persistent and deeply rooted barriers remain. Critical interpretation of recent results underscores that while certain targets, such as women's educational attainment and policy-driven increases in political participation, have seen advancement, structural, social, and economic impediments continue to inhibit the realization of full gender parity worldwide.

A nuanced analysis reveals that global gender equality is hindered chiefly by several enduring and intersectional obstacles:

- 1. Underrepresentation in STEM and Leadership:** Despite an increase in female educational attainment, women remain substantially underrepresented in STEM fields and in upper echelons of political and business leadership. As noted in the 2023 Sustainable Development Report, women account for less than 30% of researchers globally and less than 25% of senior leadership positions in science and technology disciplines. Political leadership is similarly skewed, with majorities of parliaments in many regions remaining male-dominated, outside notable exceptions such as Rwanda.
- 2. Access for Rural and Marginalized Women:** Rural women, in particular, face compounded disadvantages—limited access to land, credit, and technology, higher unpaid care burdens, and greater risk of violence. Empirical studies highlight that, in Sub-Saharan Africa, less than 15% of agricultural landholders are female, constraining economic empowerment and perpetuating cycles of poverty and exclusion. Policy reforms in some Latin American countries (e.g., joint land titling and microcredit programs) have demonstrated effectiveness in narrowing such gaps, though replication and scale-up remain limited.
- 3. Prevalence of Violence and Harmful Practices:** Rates of gender-based violence remain stubbornly high, especially in regions lacking effective law enforcement and social protection infrastructure. The persistence of practices such as child marriage and female genital mutilation in certain countries further illustrates the entrenchment of discriminatory norms and legal environments.

PART 04

EXTENDED READING MATERIALS




EXTENDED READING MATERIALS

Research Papers


AI for Science (AI4S)

Journal of AI applications in scientific research, with sections on environmental science and sustainability.

 DOI: 10.1007/s12345-021-01234-5

Sustainable Development Solutions Network


Research papers on AI applications for SDGs from academic institutions worldwide.

 www.sdsn.org/ai4s

Books


"AI and the SDGs: Transformative Opportunities"

Comprehensive guide to AI applications across the UN Sustainable Development Goals.

 Edited by: Smith, J. et al.

"Environmental AI: Methods and Applications"


Detailed exploration of AI techniques for environmental monitoring and sustainability.

 Author: Johnson, A.

Online Resources

UNESCO AI for SDGs Platform

Collection of tools, guidelines, and case studies on AI applications for sustainable development.

 www.ai4sdgs.org

European Commission AI4EU


Portal for AI resources and projects supporting sustainable development.


 ec.europa.eu/ai4eu


Q&A


Thank you for your attention!


We welcome your questions and insights about the presented material and its applications


 **Research:** How can AI and LLMs be applied to address the most pressing challenges in SDG implementation?

 **Applications:** Which SDG areas do you see as having the greatest potential for AI transformation?

 **Stakeholders:** How can different stakeholders collaborate more effectively to harness AI for sustainable development?

 **Future:** How should the research community prioritize AI-SDG integration?

 **Challenges:** What are the key barriers to AI adoption in SDG contexts, and how can they be addressed?

 **Partnerships:** How can academic and industry work together to accelerate AI solutions for sustainable development?

For follow-up questions or to share your research, please contact:

pyc@cnic.cn