

Rethink of Structural Health Monitoring in the AI Era: *A Personal Perspective*

Presented by

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Chair of Structural Dynamics

School of Civil and Environmental Engineering

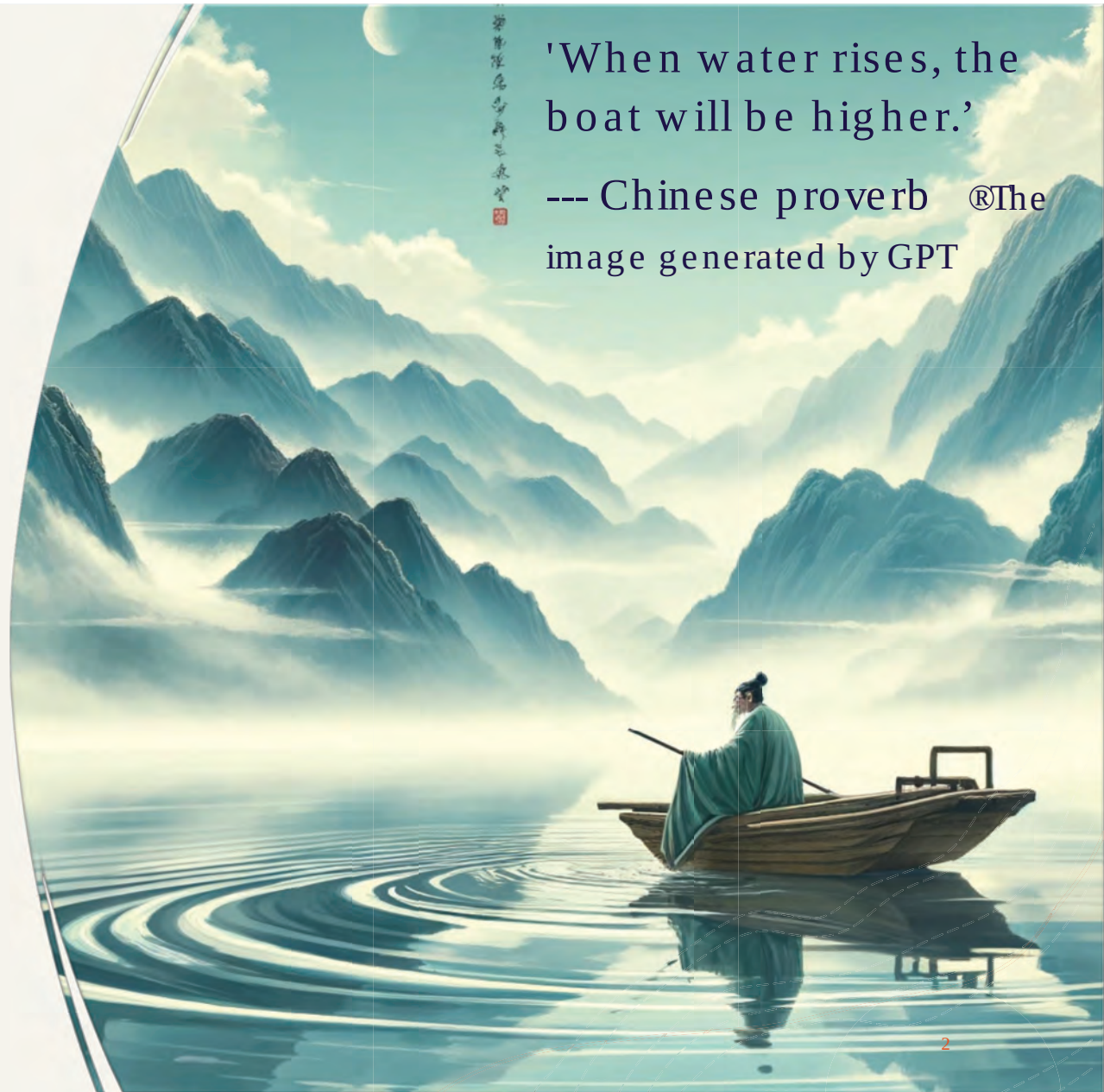
University of Technology Sydney



®The image generated by Gemini

Motivation?

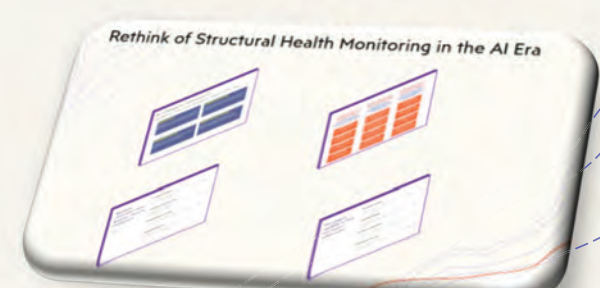
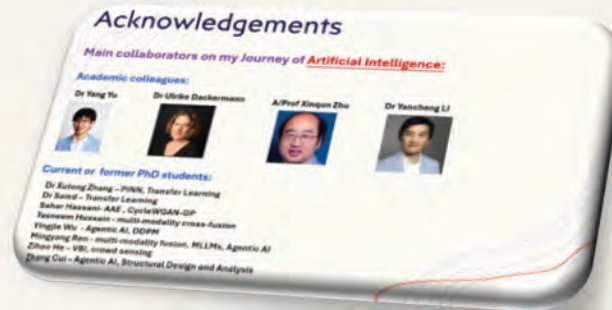
- About Australian Network of Structural Health Monitoring (ANSHM)
- Why talking AI now?
 - Promote
 - Share
 - Thrive together



'When water rises, the boat will be higher.'

--- Chinese proverb ©The image generated by GPT

My Journey of Artificial Intelligence



The journey begin with



If you want to walk fast, walk alone;

If you want to walk far, walk together.

- *An African proverb* ®The image generated by Gemini

Acknowledgements

Main collaborators on my Journey of Artificial Intelligence:

Academic colleagues:

Dr Yang Yu



Dr Ulrike Dackermann



A/Prof Xinqun Zhu



Dr Yancheng Li



Current or former PhD students:

Dr Xutong Zhang – PINN, Transfer Learning

Dr Saied – Transfer Learning

Sahar Hassani- AAE , CycleWGAN-GP

Tasneem Hussain - multi-modality cross-fusion

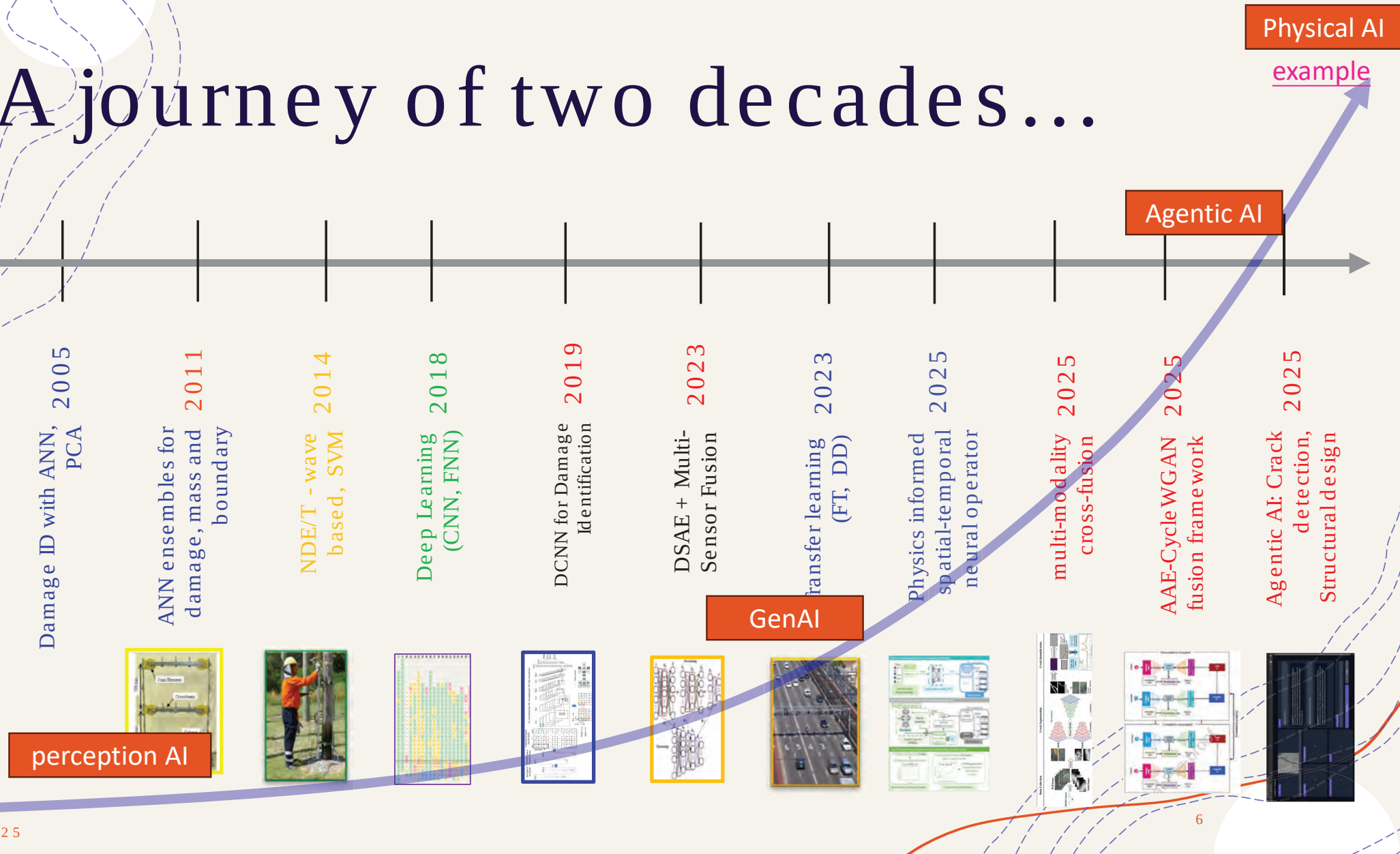
Yingjie Wu - Agentic AI, DDPM

Mingyang Ren - multi-modality fusion, MLLMs, Agentic AI

Zihao He – VBI, crowd sensing

Zhang Cui – Agentic AI, Structural Design and Analysis

A journey of two decades...

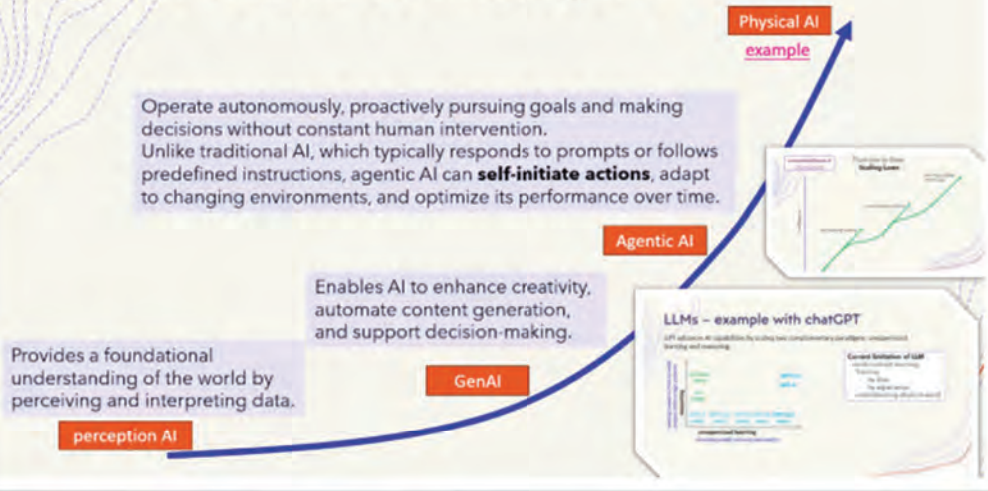


What's going on? - Era of Intelligence Explosion

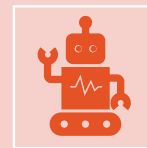
Growth of Artificial Intelligence

where your 'latest update' is already vintage by lunchtime!

Growth of Artificial Intelligence



LLM and LWM



Agentic AI, e.g coding agents:
OpenAI Codex,
Anthropic Claude 4



Google Deepmind AlphaEvolve



Growth of Artificial Intelligence

Operate autonomously, proactively pursuing goals and making decisions without constant human intervention.
Unlike traditional AI, which typically responds to prompts or follows predefined instructions, agentic AI can self-initiate actions, adapt to changing environments, and optimize its performance over time.

Physical AI

example

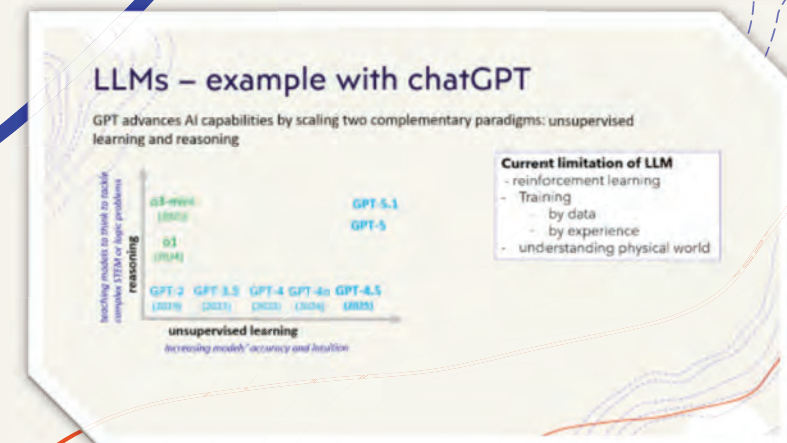
Agentic AI

Enables AI to enhance creativity, automate content generation, and support decision-making.

GenAI

Provides a foundational understanding of the world by perceiving and interpreting data.

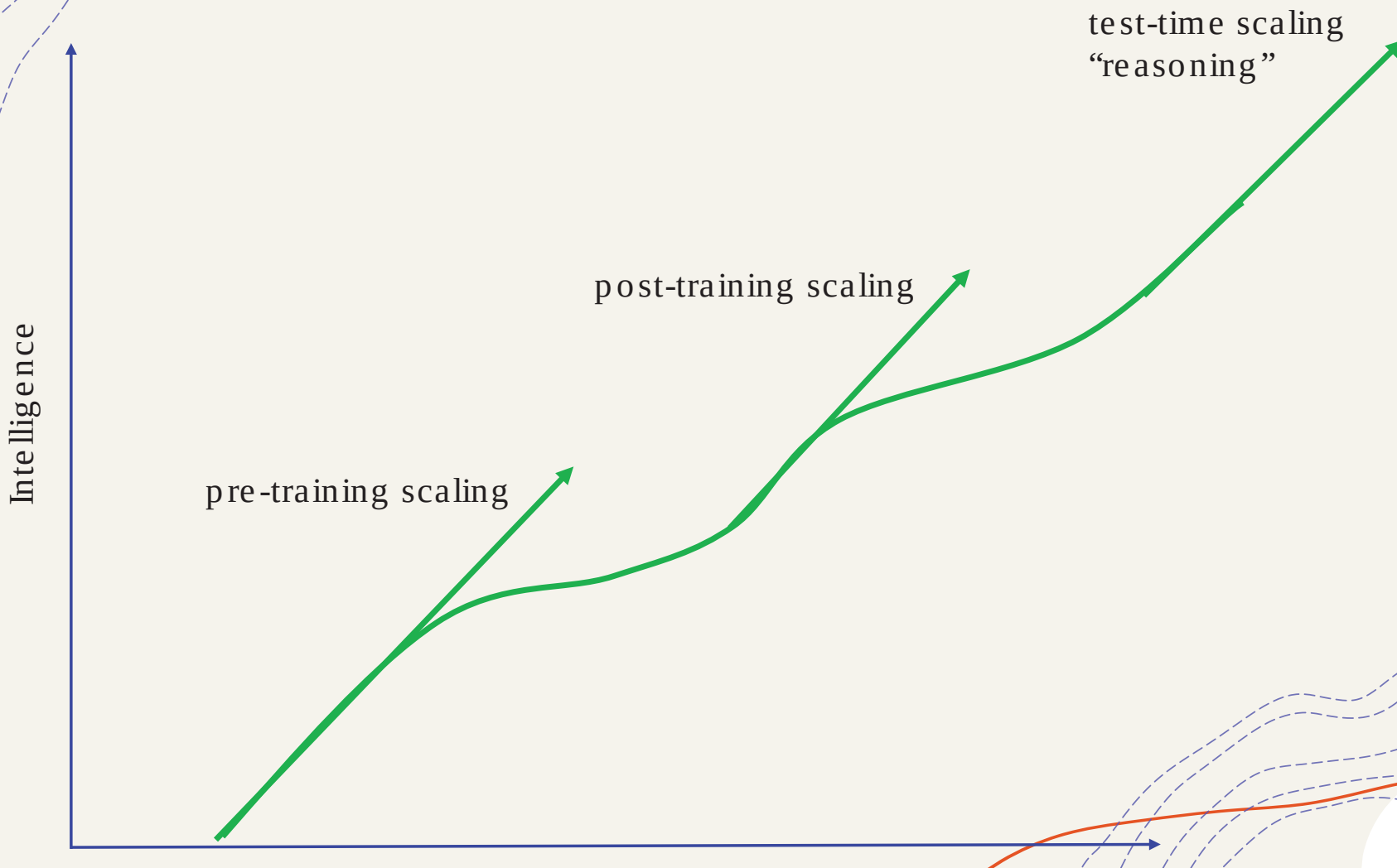
perception AI



Unreasonably Effective AI

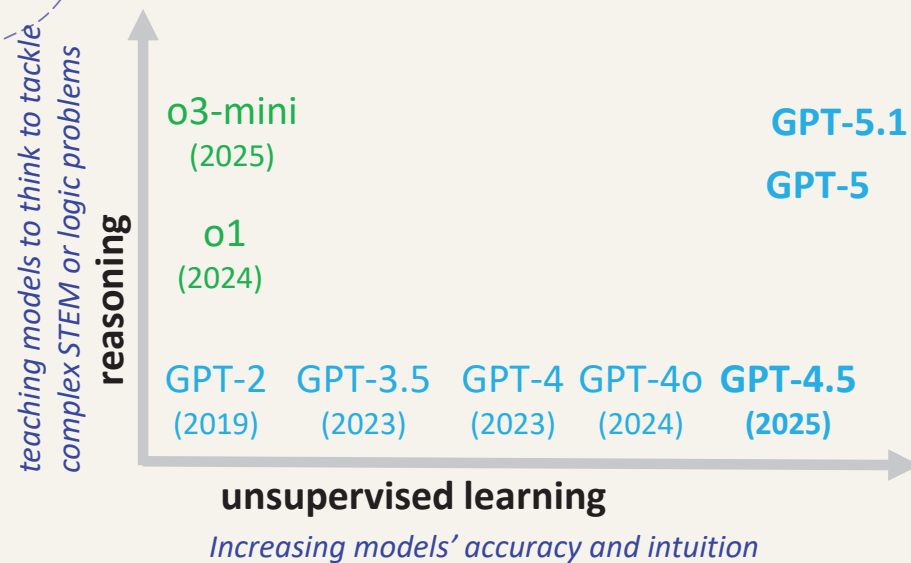
with Demis Hassabis

From one to three Scaling Laws



LLMs – example with chatGPT

GPT advances AI capabilities by scaling two complementary paradigms: unsupervised learning and reasoning

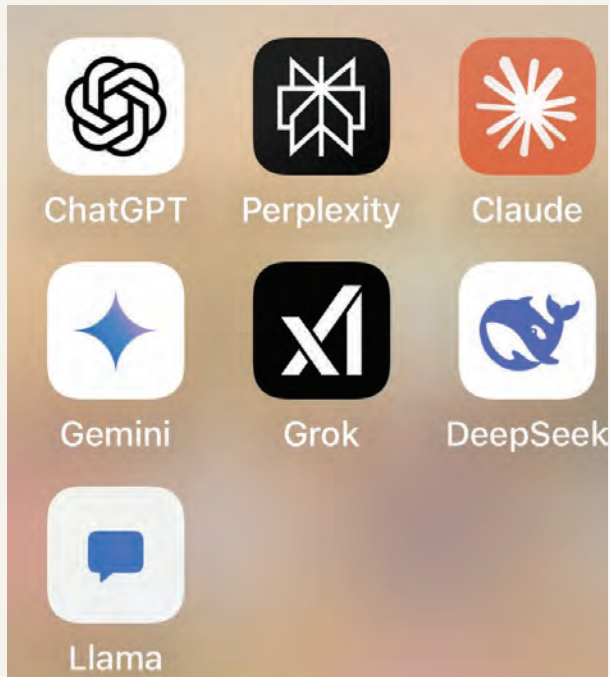


Current limitation of LLM

- reinforcement learning
- Training
 - by data
 - by experience
- understanding physical world

LLMs and LWMs

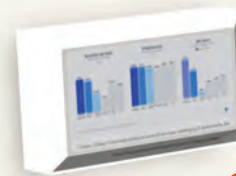
Large Language Models (LLMs)



Large World Models (LWM)

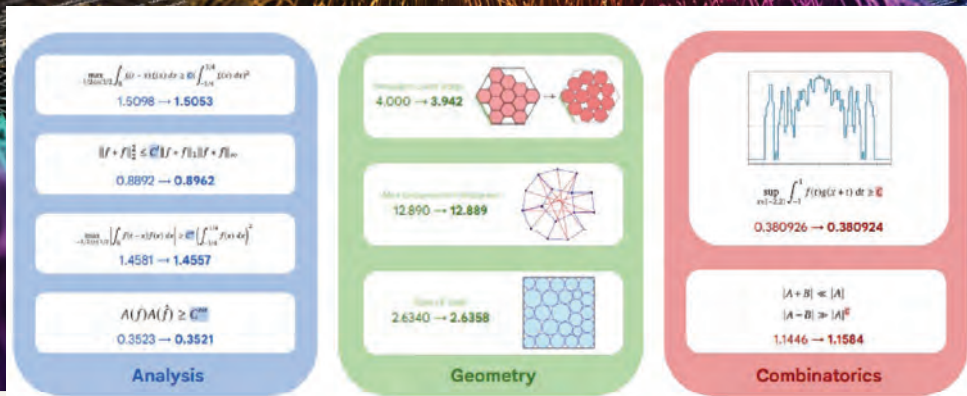
- Google DeepMind ([Genie 3](#))
- [deepmind.google](#)
- World Labs ([Marble](#))
- [wired.com](#)
- PhysicsX and Siemens Collaboration
- [newsroom.sw.siemens.com](#)

[Google Gemini 3](#)



AlphaEvolve

- *an autonomous evolutionary coding agent*



- o optimizing data center scheduling at Google
- o simplifying **hardware** circuit designs
- o accelerating the training of the LLMs that power AlphaEvolve
- o **discovered new**, provably correct algorithms that outperform current state-of-the-art methods in mathematics and computer science.
- o **Made** the first improvement over Strassen's algorithm in this domain in 56 years: the discovery of a novel procedure for multiplying two 4x4 complex-valued matrices using only 48 scalar multiplications

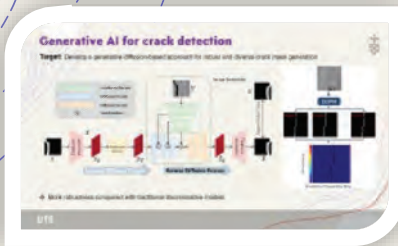
Reference:

<https://deepmind.google/discover/blog/alphaevolve-a-gemini-powered-coding-agent-for-designing-advanced-algorithms/>

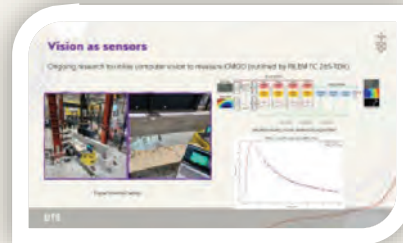
More example AI research at UTS

- AI4C (Artificial Intelligence for Civil Engineering) Lab

Research leaders: Dr Yancheng Li, Prof Jianchun Li



Generative AI for crack detection



Vision as sensors



LLM4CD – AI enabled decision making



Quantification of thin crack with AI



Development of Agentic AI



Harbour Bridge ,
1932



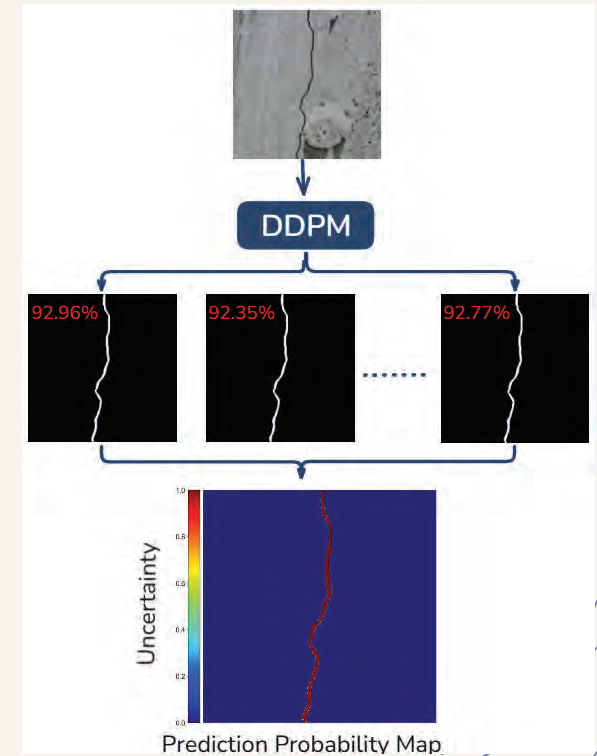
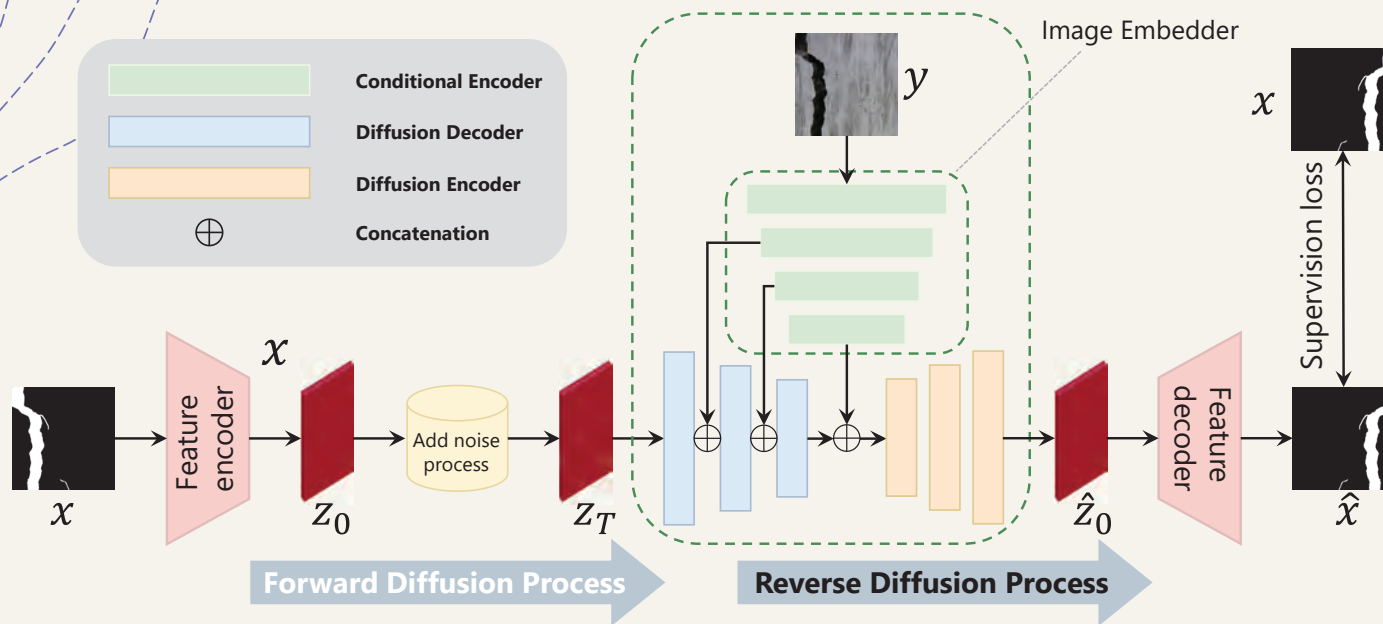
Anzac Bridge ,
1995



Three Gorges Dam ,
2006

Generative AI for crack detection

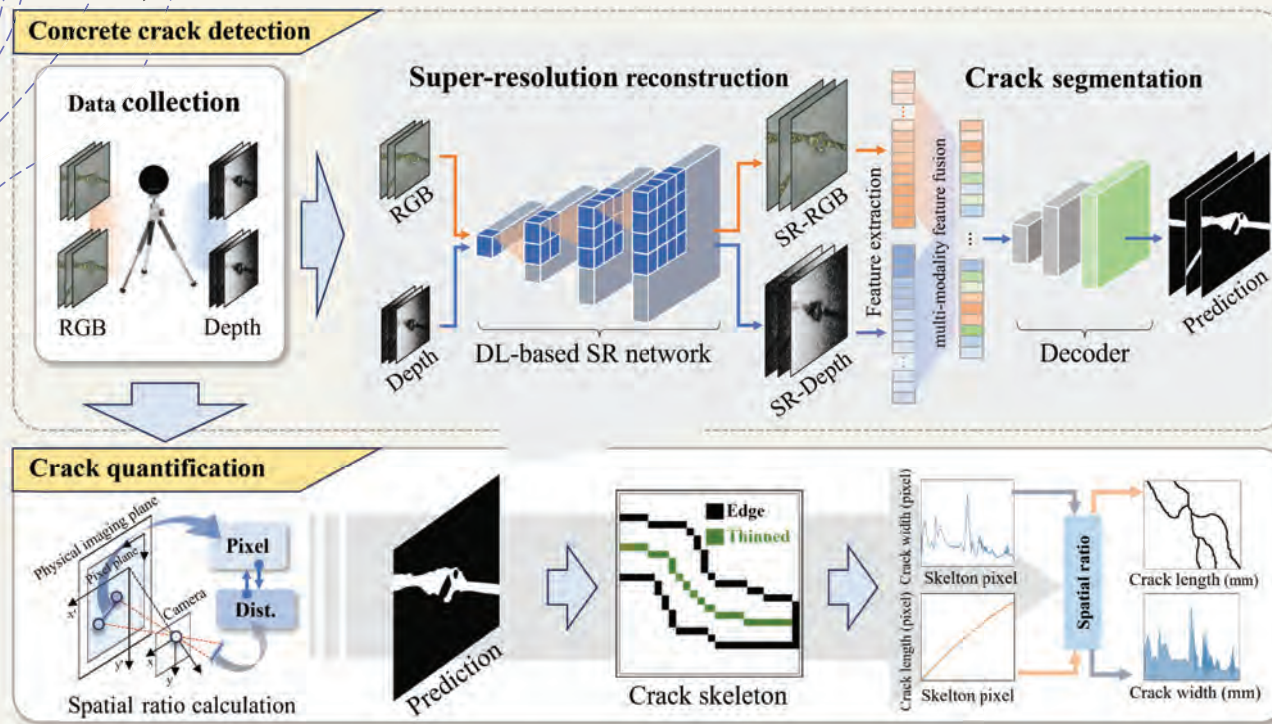
Target: Develop a generative diffusion-based approach for robust and diverse crack mask generation



❖ More robustness compared with traditional discriminative models

Quantification of thin Crack with AI

Standards/regulations, AS 3735/AS5100.5, require to detect thin concrete crack (width from 0.1 - 0.3 mm)



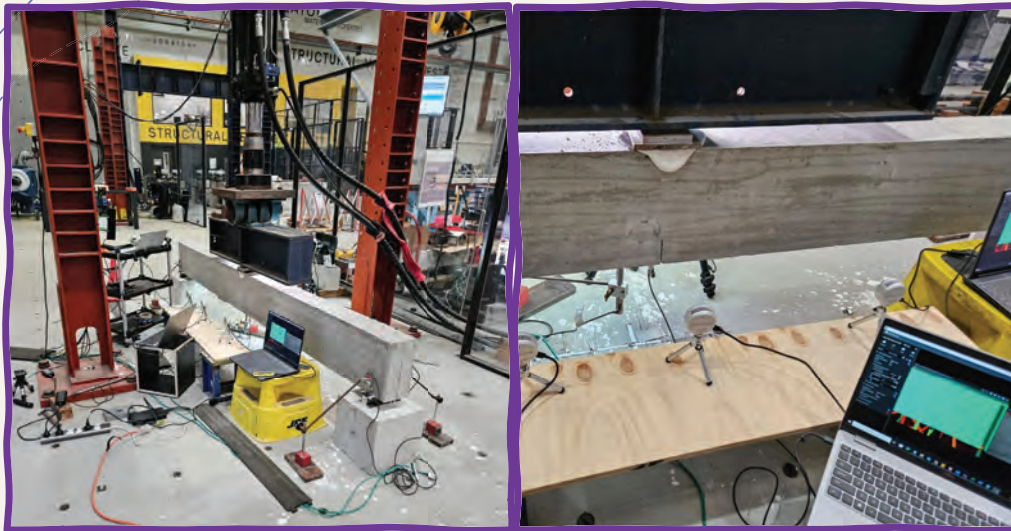
Overall architecture of proposed crack quantification algorithm.

Integrated framework for high-precision and robustness thin crack detection and quantification

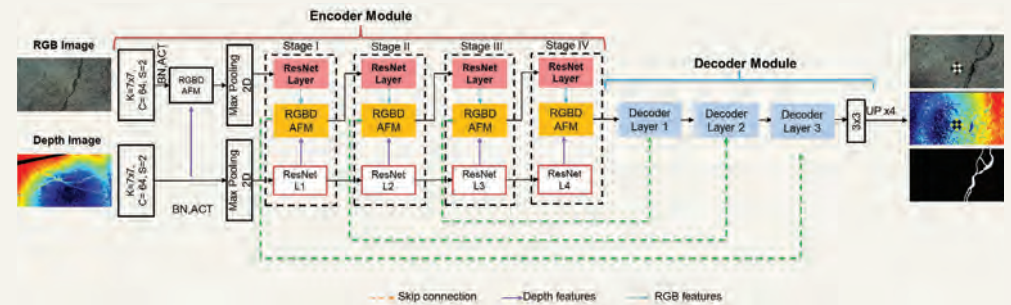
- Multimodality information fusion
- Capable of identifying cracks as narrow as **0.1 mm**
- Automated and consistent results
- Robust performance in challenging backgrounds

Vision as sensors

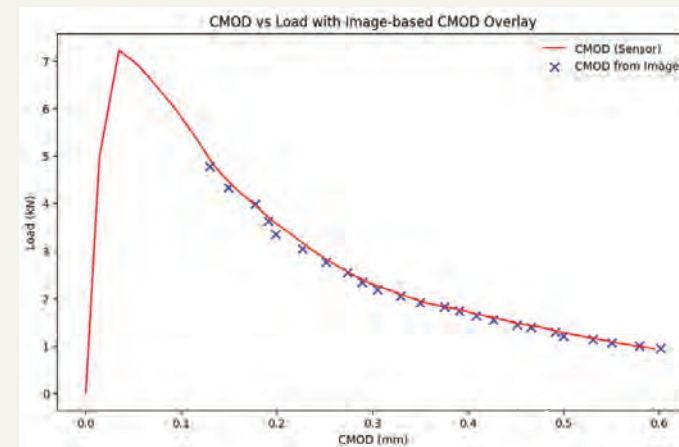
Ongoing research to utilise computer vision to measure CMOD (outlined by RILEM TC 265-TDK)



Experimental setup

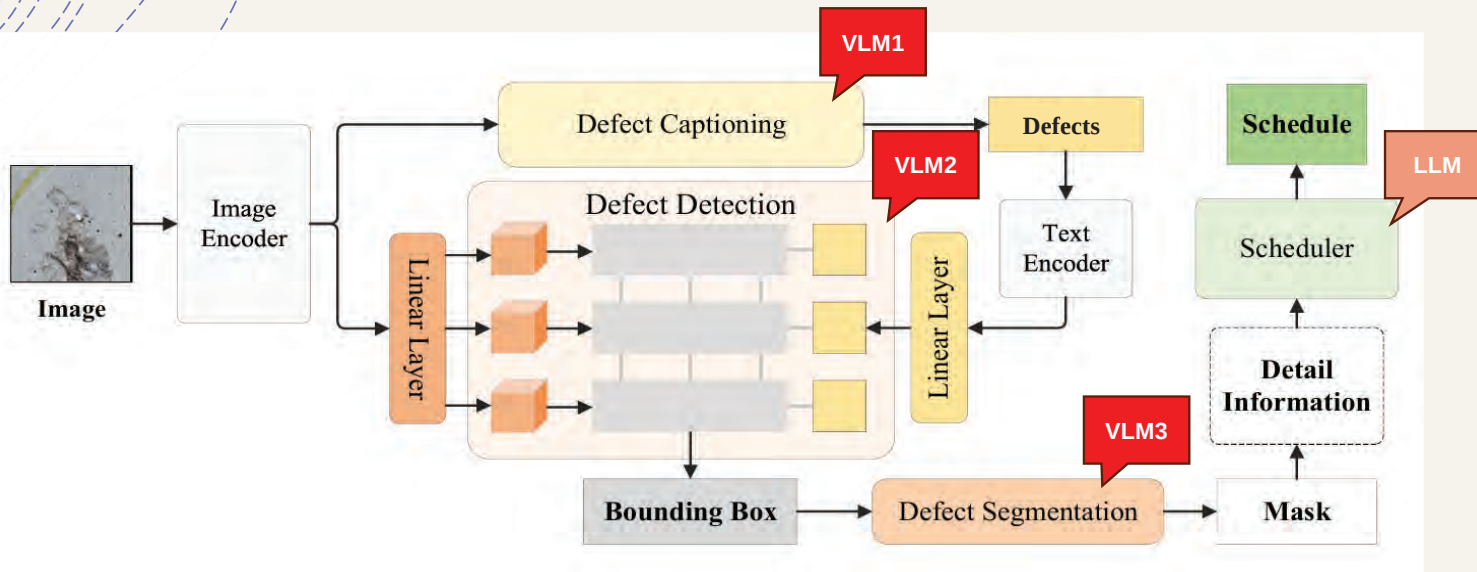


Multimodality crack detection algorithm

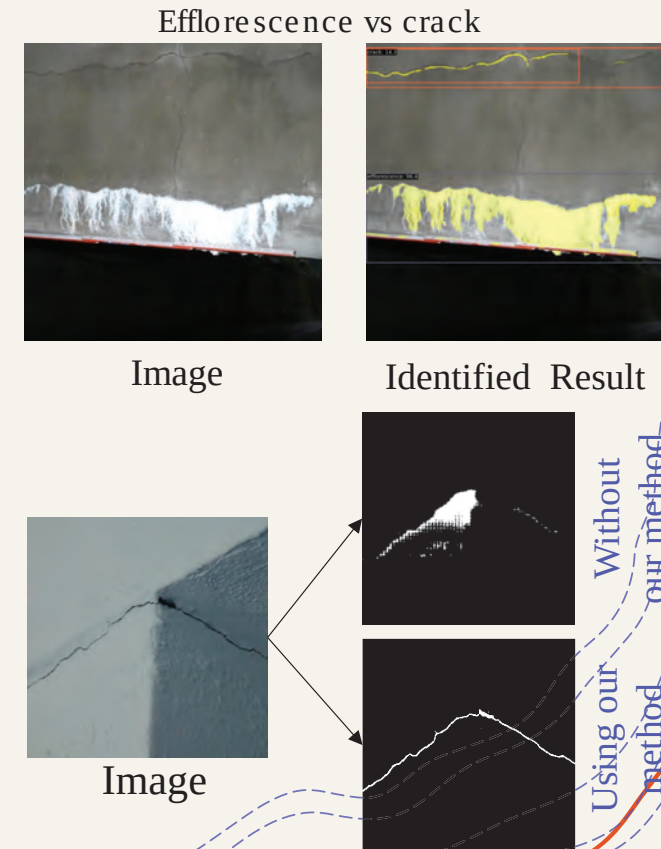


LLM4CD – AI enabled decision making

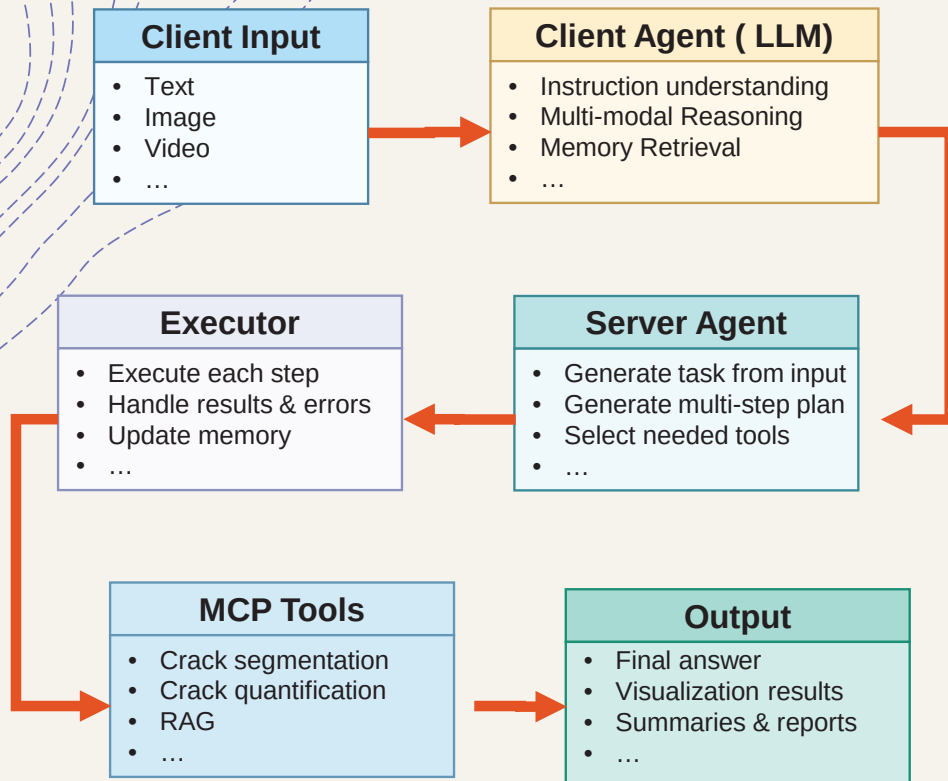
A large visual language model-driven pipeline for automated concrete **defect detection**, **quantification**, and **repair scheduling**.



Overall architecture of the proposed concrete defect detection2decision workflow.



Development of Agentic AI for Crack Identification



Agentic AI integrating deep learning crack detection and LLM

Rethink of Structural Health Monitoring in the AI Era



An Intelligent Collaborator?

perception, reasoning, adaptation, human-in-the-loop

Perception in AI

AI performs multi-modal pattern recognition even with noisy and incomplete data inputs.

Adaptation via Learning

AI uses continual learning to adapt over time to aging, environment, and usage changes.

Reasoning and Inference

AI fuses models and measurements to infer states and assess risks accurately.

Human-in-the-Loop Interaction

Engineers set goals and constraints; AI proposes solutions and explains decisions.

Shift #1—Reactive → Proactive Intelligence

From fault detection to prediction and intervention

Predictive Assessment

Identify precursors like trends, drifts, and anomalies to predict faults before occurrence.

Risk-Based Maintenance

Rank inspections and maintenance schedules according to predicted risk levels for efficiency.

Closed Loop Process

Implement a cycle of observe, predict, intervene, and re-monitor to improve system uptime

Operational Benefits

Proactive intelligence reduces downtime, surprises, and optimizes resource allocation.

Shift #2 —Deterministic → Self-Evolving Digital Twins

Living digital twins:
hybridization, calibration,
scenario testing

Hybridization for Robustness

Combining physics-informed and data-driven methods enables resilient self-evolving digital twins.

Online Environmental Calibration

Dynamic calibration adjusts twins to temperature, humidity, loading, and aging effects in real-time.

Scenario Testing

Simulating interventions and what-if analyses helps predict outcomes before actual actions are taken.

Traceability and Uncertainty

Versioned twin states track evolution with attached uncertainties for reliable decision making.

Shift #3 —Supervision → Human-AI Co-Agency

Shared awareness and
decision-making between
engineers and AI

Human Role Definition

Engineers set objectives, constraints, and acceptance criteria guiding AI actions.

AI Proposal with Confidence

AI suggests ranked interventions supported by rationale and confidence levels.

Interactive Decision Tools

Interfaces offer explanations, confidence metrics, and what-if analysis tools for clarity.

Governance and Accountability

Logs and audits ensure transparency and traceability of AI suggestions and decisions



Resilience, uncertainty-aware decisions, lifecycle management

Designing for Resilience &
Uncertainty

Resilience Principles

Incorporate redundancy, sensing diversity, and fail-safe defaults to enhance system resilience.

Uncertainty-Aware Decisions

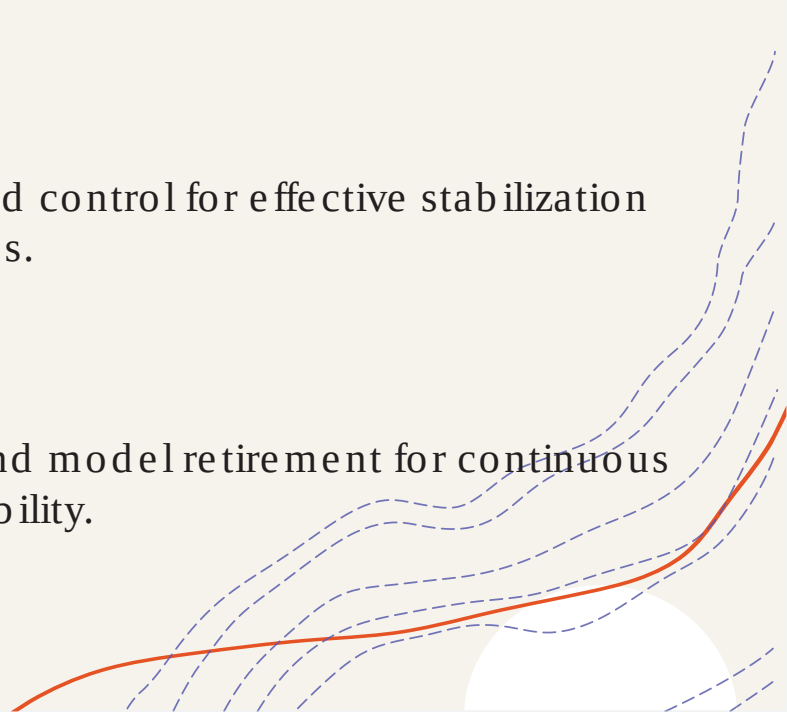
Make decisions to act, defer, or inspect based on confidence levels and uncertainty assessments.

Integrated Control Systems

Combine sensing, analytics, and control for effective stabilization and rapid recovery from failures.

Lifecycle Management

Manage updates, retraining, and model retirement for continuous system improvement and reliability.





Pilot projects, capability building, trust metrics, collaboration

Invitation & Next Steps

Pilot Projects Setup

Have clear objectives, measurable metrics, and defined guardrails to ensure success and safety.

Capability Building

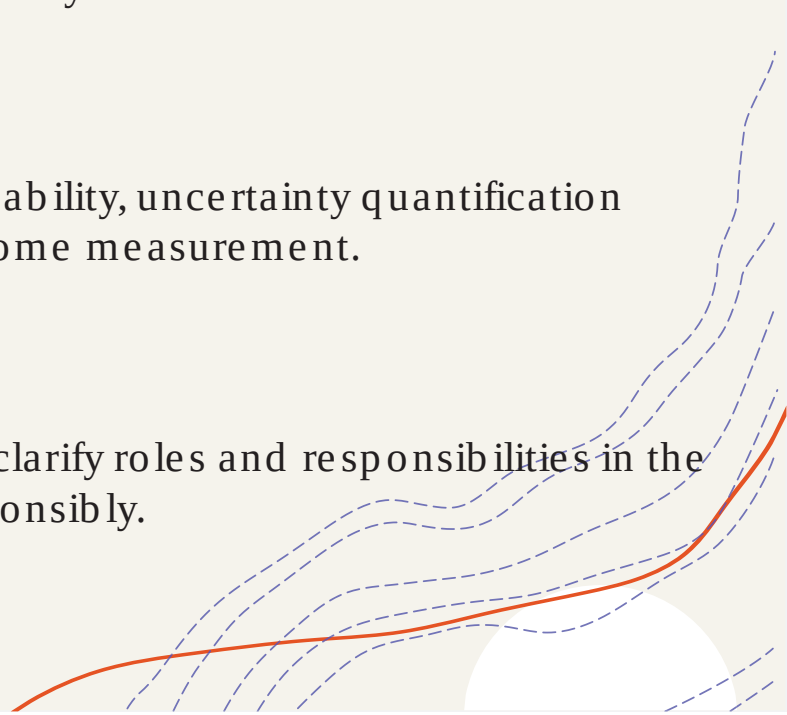
Build capabilities by aligning SHM, data, and operations teams to work collaboratively and efficiently.

Trust Metrics Importance

Establish trust through explainability, uncertainty quantification calibration, and accurate outcome measurement.

Collaboration and Roles

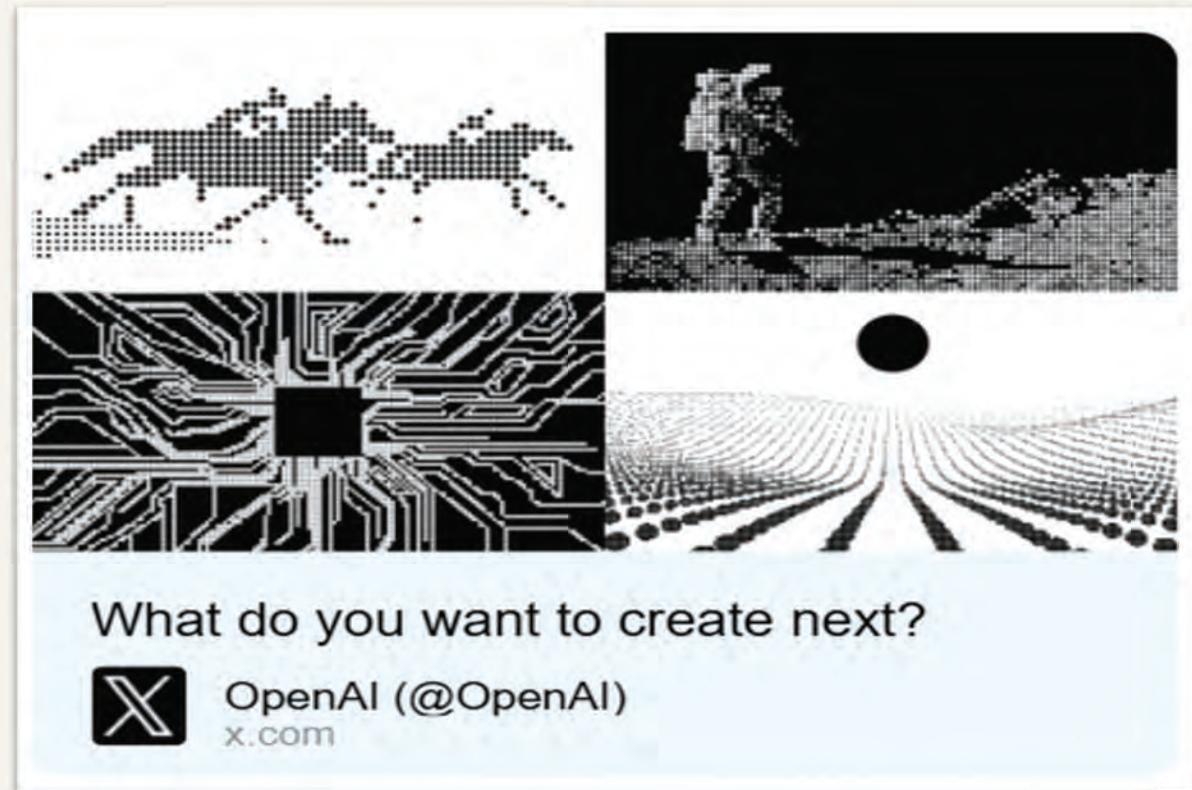
Encourage collaboration and clarify roles and responsibilities in the AI era to drive innovation responsibly.

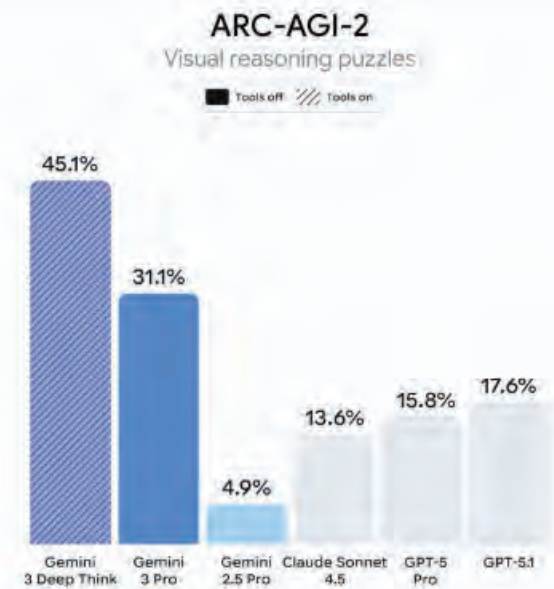
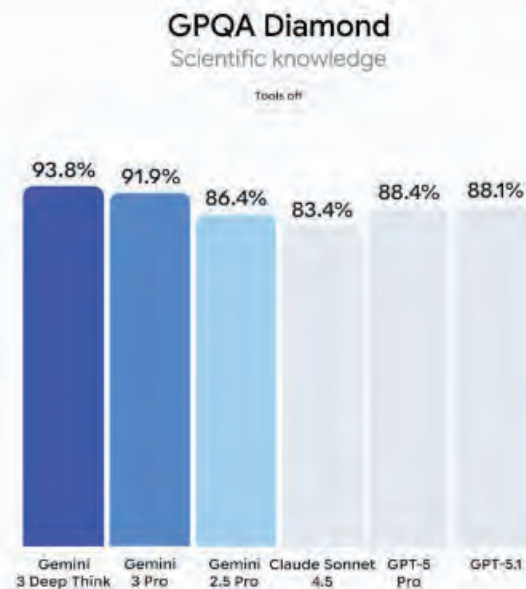
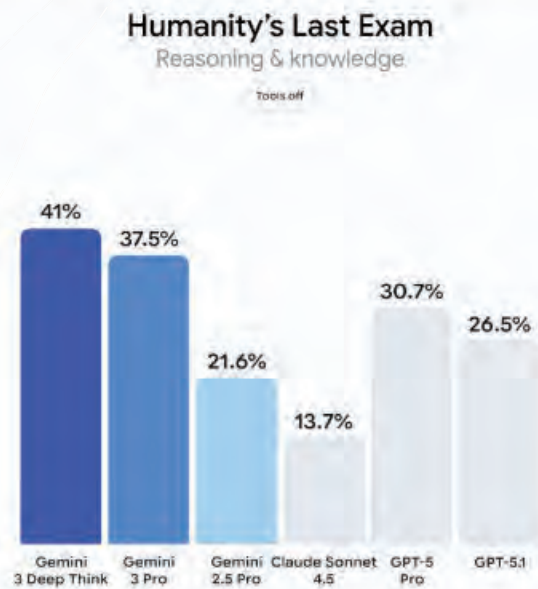


End of the Presentation

Thank you for
your attentions!

Any Question?





*Methodology: deepmind.google/models/evals-methodology/gemini-3-pro



Gemini 3 Deep Think mode excels on some of the most challenging AI benchmarks. See

<https://blog.google/products/gemini/gemini-3/#learn-anything>

Benchmark	Description		Gemini 3 Pro	Gemini 2.5 Pro	Claude Sonnet 4.5	GPT-5.1
Humanity's Last Exam	Academic reasoning	No tools	37.5%	21.6%	13.7%	26.5%
		With search and code execution	45.8%	—	—	—
ARC-AGI-2	Visual reasoning puzzles	ARC Prize Verified	31.1%	4.9%	13.6%	17.6%
GPQA Diamond	Scientific knowledge	No tools	91.9%	86.4%	83.4%	88.1%
AIME 2025	Mathematics	No tools	95.0%	88.0%	87.0%	94.0%
		With code execution	100%	—	100%	—
MathArena Apex	Challenging Math Contest problems		23.4%	0.5%	1.6%	1.0%
MMMU-Pro	Multimodal understanding and reasoning		81.0%	68.0%	68.0%	76.0%
ScreenSpot-Pro	Screen understanding		72.7%	11.4%	36.2%	3.5%
CharXiv Reasoning	Information synthesis from complex charts		81.4%	69.6%	68.5%	69.5%
OmniDocBench 1.5	OCR	Overall Edit Distance, lower is better	0.115	0.145	0.145	0.147
Video-MMMU	Knowledge acquisition from videos		87.6%	83.6%	77.8%	80.4%
LiveCodeBench Pro	Competitive coding problems from Codeforces, ICPC, and IOI	Elo Rating, higher is better	2,439	1,775	1,418	2,243
Terminal-Bench 2.0	Agentic terminal coding	Terminus-2 agent	54.2%	32.6%	42.8%	47.6%
SWE-Bench Verified	Agentic coding	Single attempt	76.2%	59.6%	77.2%	76.3%
t2-bench	Agentic tool use		85.4%	54.9%	84.7%	80.2%
Vending-Bench 2	Long-horizon agentic tasks	Net worth (mean), higher is better	\$5,478.16	\$573.64	\$3,838.74	\$1,473.43
FACTS Benchmark Suite	Held out internal grounding, parametric, MM, and search retrieval benchmarks		70.5%	63.4%	50.4%	50.8%
SimpleQA Verified	Parametric knowledge		72.1%	54.5%	29.3%	34.9%
MMMLU	Multilingual Q&A		91.8%	89.5%	89.1%	91.0%
Global PIQA	Commonsense reasoning across 100 Languages and Cultures		93.4%	91.5%	90.1%	90.9%
MRCR v2 (8-needle)	Long context performance	128k (average)	77.0%	58.0%	47.1%	61.6%
		1M (pointwise)	26.3%	16.4%	not supported	not supported

For details on our evaluation methodology please see deepmind.google/models/evals-methodology/gemini-3-pro

Google Nano Banana

– Large World Model (e.g. [Genie 3](#))

Remove objects



Combine images



Timeline prediction



Understanding a picture

Google Nano Banana
– a dish to the recipe and graphic ingredients

Crispy Honey Soy Garlic Chicken
This recipe focuses on achieving two key things from the photo: an ultra-crispy chicken exterior that stays crunchy, and a sweet, savory, and aromatic garlic sauce that coats every piece perfectly. The secret is double-frying the chicken.

Ingredient	Amount
Chicken	1.5 lbs
Garlic	4 cloves
Soy Sauce	1/4 cup
Honey	2 tbsp
Oil	2 cups
Garlic Powder	1 tsp
Salt	1/2 tsp
Black Pepper	1/4 tsp
Red Pepper Flakes	1/4 tsp
Hot Sauce	1/4 cup
Chicken Stock	1/2 cup
Garlic	4 cloves
Soy Sauce	1/4 cup
Honey	2 tbsp
Oil	2 cups
Garlic Powder	1 tsp
Salt	1/2 tsp
Black Pepper	1/4 tsp
Red Pepper Flakes	1/4 tsp
Hot Sauce	1/4 cup
Chicken Stock	1/2 cup



Google Nano Banana

– a dish to the recipe and graphic ingredients

Crispy Honey Soy Garlic Chicken

This recipe focuses on achieving two key things from the photo: an ultra-crispy chicken exterior that stays crunchy, and a sweet, savory, and aromatic garlic sauce that coats every piece perfectly. The secret is double-frying the chicken

Category	Ingredient	Quantity
For the Chicken	Boneless, skin-on chicken thighs	~1 kg (2.2 lbs)
	Salt	1 tsp
	Black Pepper	½ tsp
	Ginger, grated	1 tbsp
For the Coating	Garlic, minced	2 cloves
	Potato Starch (or Cornstarch)	1 cup
	All-Purpose Flour	½ cup
For the Sauce	Soy Sauce	½ cup
	Honey (or corn syrup for extra gloss)	½ cup
	Mirin (or Rice Wine)	2 tbsp
	Rice Vinegar	1 tbsp
	Garlic, finely minced	8-10 cloves
	Ginger, finely minced	1 tbsp
	Sesame Oil	1 tsp
For Frying	Neutral Oil (e.g., Canola, Vegetable)	~4-6 cups
For Garnish	Fresh Parsley or Chives, finely chopped	2 tbsp

