Research Services in NCHC

Chun-Yu Lin 林俊鈺

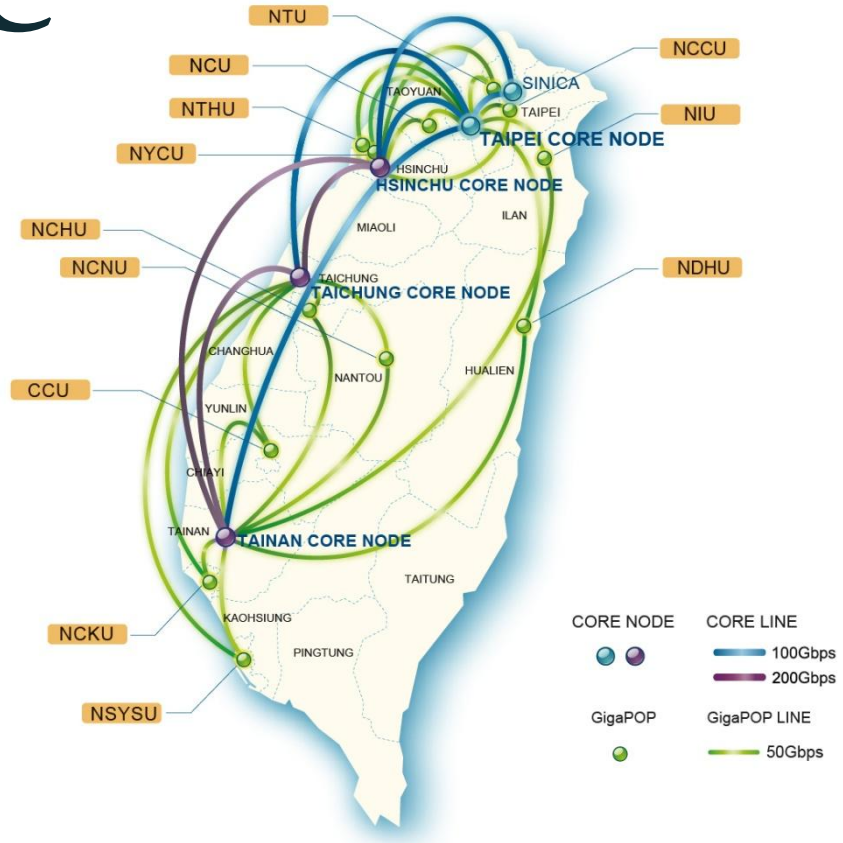
Hsinchu HQ (1993)

Taichung (2008)

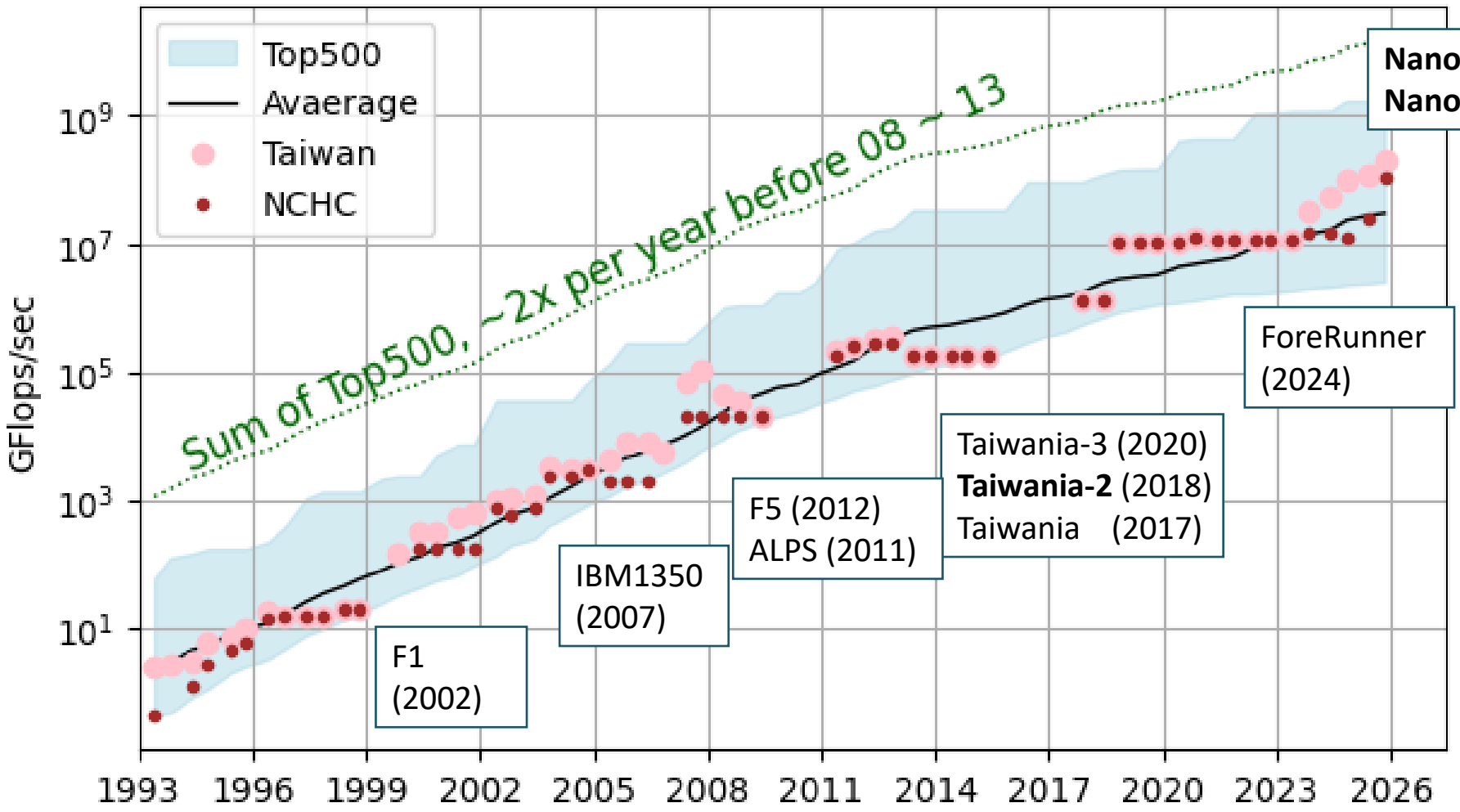
Tainan (2005)

Shalun (2018)

Tainan IDC (2025 Dec)



NCHC & Top500

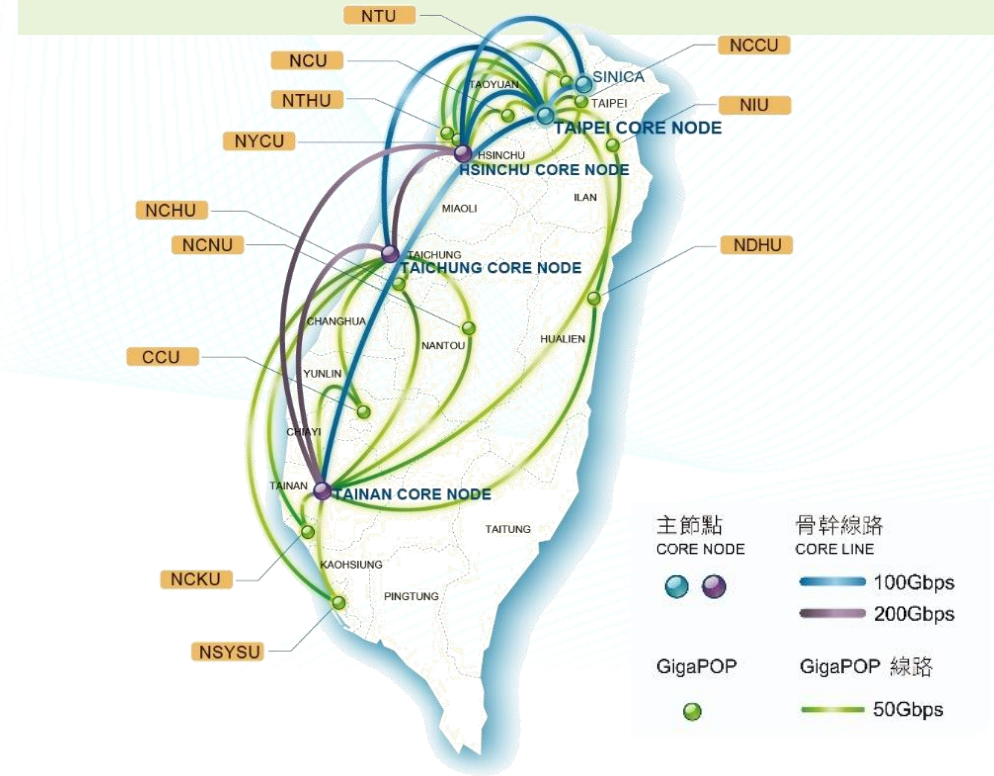


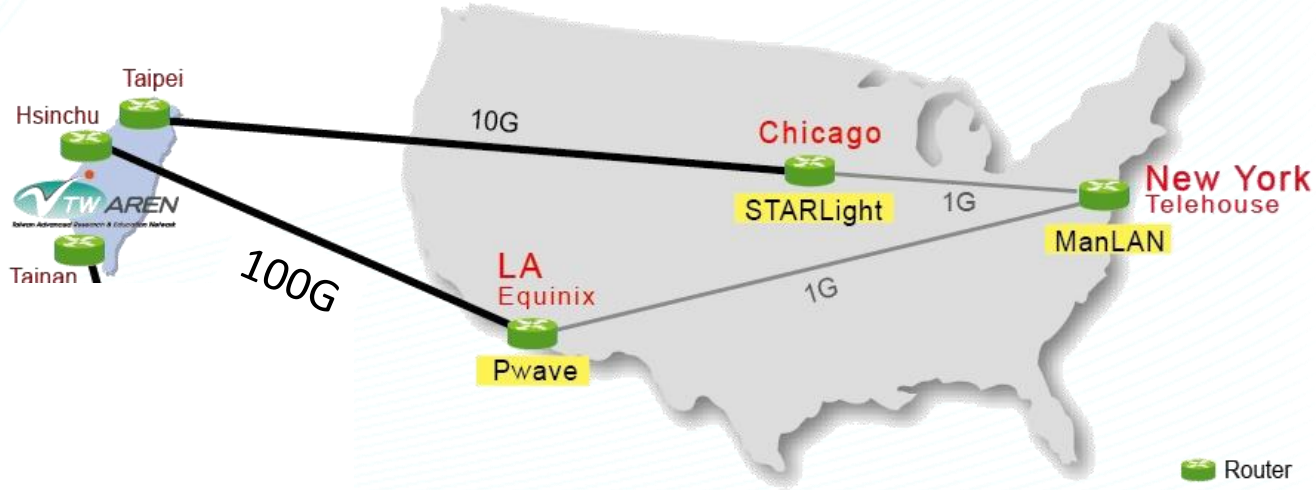
- Based on HPL (FP64).
- Driven by advances in hardware, microarchitecture, and software.
- `08-13 slowdown due to power constraints, even worse for low-ranked system

TaiWan Advanced Research and Education Network

- Optical dedicated bandwidth in island
  - ✓ **20G (2004) → 200G (2008) → 4*400G (2026)**
  - ✓ 12 GigaPOPs
  - ✓ 94 universities & research institutes
  - ✓ 500k+ users

- Sharing network fiber with **TANet**
  (4000+ schools, 4.5m+ users)
- Availability: 99.99%+
- 110 Gbps links to **LA, Chicago**
  (thru which peering to other RENs)





Supercomputers, Network, and IDC (Internet Data Center)

HPC & cloud

台灣杉 TAIWANIA

2018
Twnia2 9 PF

2019
Twnia3 2.7 PF

2023
TAIDE
3.8 PF

2022
FORMOSA OPEN EXCHANGE
Formosa Open eXchange

2024
Forerunner
3.4 PF

2023
Self-built fiber backbone Initiated

2025
Nano 5
13 PF

2025
Tainan IDC
15MW

2026
Nano 4
81.5 PF

2026
4 x 400Gbps
fiber backbone
scheduled for activation

2028
HPC-X Quantum integrated

2029
Shalun IDC
90MW

Network & data center

2004
TWAREN

User profile (2026)

- **1 k+** project groups and **11 k+** users:
  ~ 80% NSTC
  ~ 20% Gov,
  < 1 % Industry (by usage)

- NSTC domain usage breakdown:
  ~ **40 %** Math/Phy/Chem
  < 30 % Engineering (Material/IT/Semicon)
  ~ 26 % Environments, Others
  ~ 5 % Biomedic

HPC in services:

- Nano4
  - 81.5 PF, 8*220 H200, 37 GF/W , PUE~1.18
  - Top 29 and Green 73 @ Nov 2025
- Nano5
  - 13 PF, 296 H100/H200, 30 GF/W , PUE~1.25
  - Top 118 and Green 73 @ Jun 2025
- Forerunner (CPU-based from ASUS)
  - 3.4 PF, 62k-core, 5.7 GF/W, PUE~1.35
  - Top 222 and Green 92 @ Nov 2023
- Twnia-3 (CPU)
- Twnia-2 (GPU)

Applications

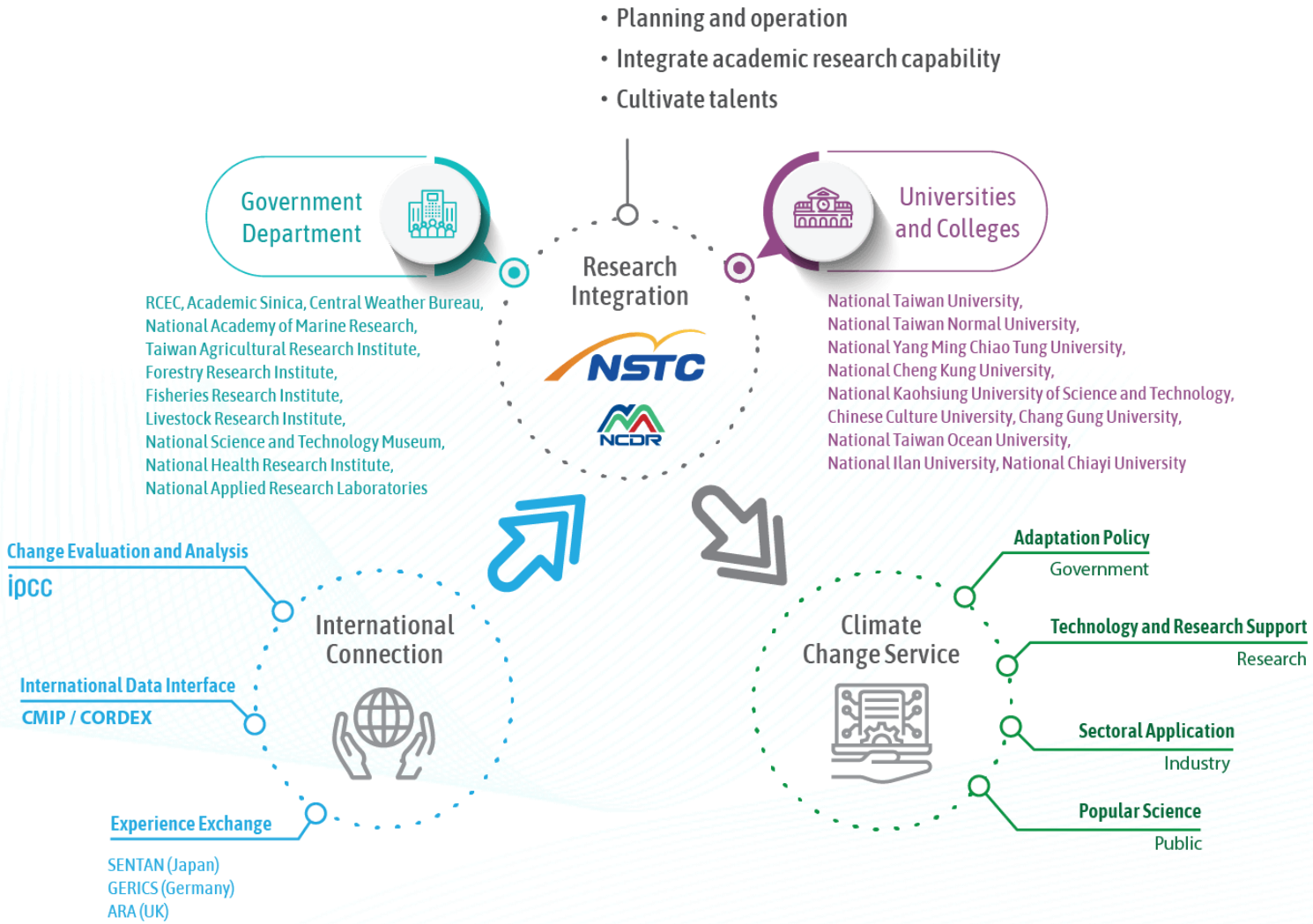
- Climate, Weather & Environment
- Health & Biology
- Material, Energy & Chemistry
- Engineering
- Space, Plasma & Physics
- AI, Quantum computing
  - New paradigms and challenging HPC applications.

Challenges of our time, from environment and health,
to the global sustainability and exploration of unknown

Research & Platform Services

- TCCIP (Taiwan Climate Change Projection Information) Adaptation Knowledge Platform
  臺灣氣候變遷推估資訊與調適知識平台
- Smart city, 3D GIS, Civil IoT Taiwan
- Ocean negative carbon research platform: from seismic reflection data portal to CCS simulation
- Sustainable Health Big Data Platform (健康大數據) & Taiwan biobank (台灣人體生物資料庫)
- GIS for precision agriculture
- Material platform (adv structural materials based on high-entropy alloy) & Semiconductor research
- PCB warpage analysis & Cloud platform
- Render farm
- Nuclear fusion simulation for FIRST
- WLCG/IGWN Grid computing
- Taiwan AI RAP - Sovereign AI and AI democratization, Multilingual Indigenous Language AI/LLM
- Quantum computing…

Taiwan Climate Change Projection Information & Adaptation Knowledge Platform



- The 4-th phase TCCIP (2009~) strengthen **cross-level and cross-sector adaptation** applications to support SDGs.
- Respond to climate emergency and enhance systematic resilience of Taiwan.
- NCHC in **Team3** :
  - Information outlet & Web services
  - Promote and operate climate change services & integrated platform, data store and adaptation resources kit.

TEAM1 Data Generation and Trend Analysis

TEAM2 Impact and Adaptation Application

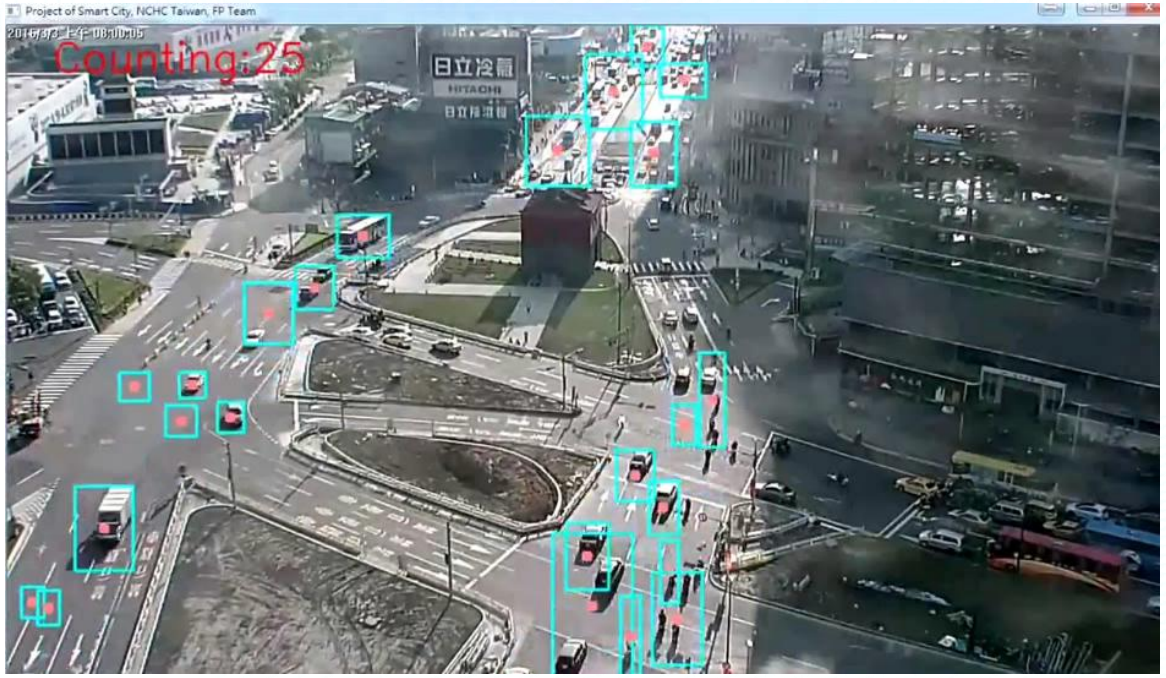
TEAM3 Climate Change Service and Application Promotion

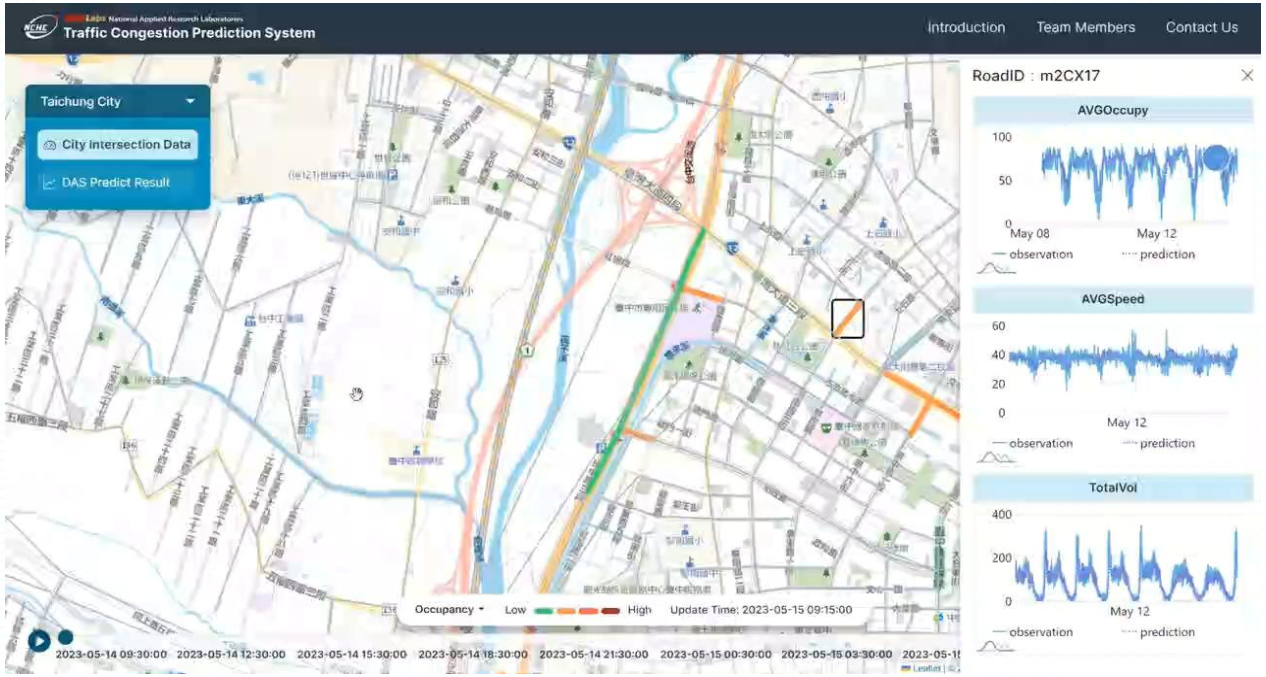
Core members: Steven Shiau 蕭志榤
Jen-Gaw Lee 李正國, Tzumin Chuang 莊子民

https://tccip.ncdr.nat.gov.tw/

Smart city & Urban governance

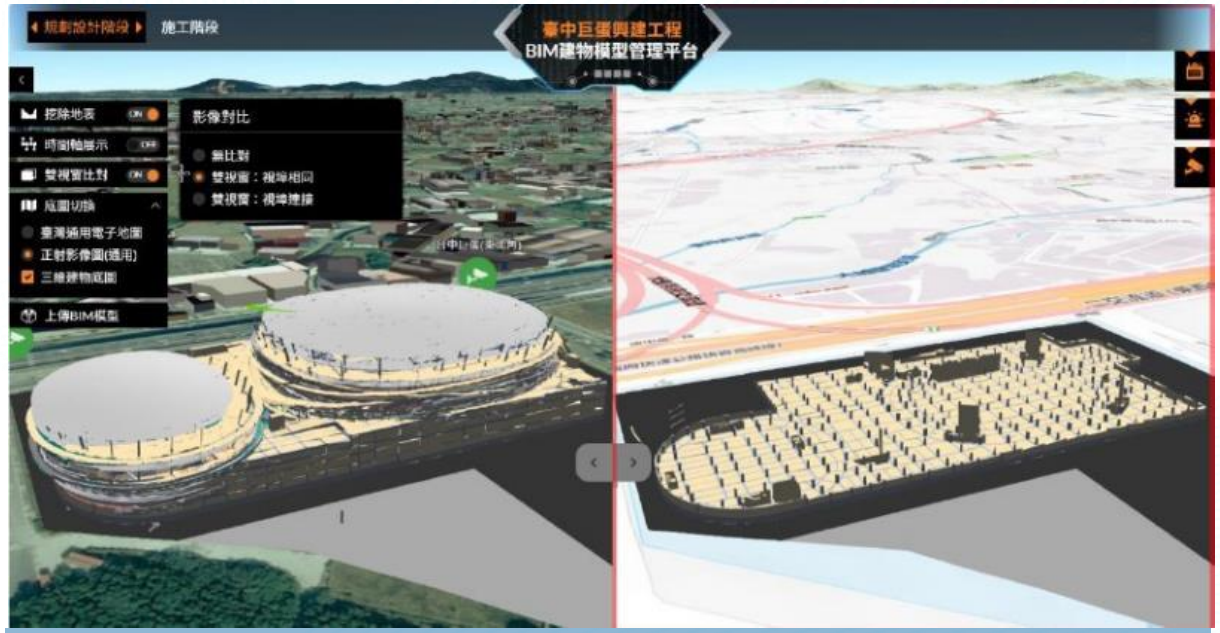
- Predictive traffic analytics: 30-minute road condition forecast.
- Smart policing: multimodal street video recognition for surveillance footage; LLM-aided investigation.
- Accuracy Championship of ICCV 2025 AI City Challenge
- Taichung City: Recognized with **2025 Excellence in City Governance Award** by CommonWealth Magazine (天下雜誌)



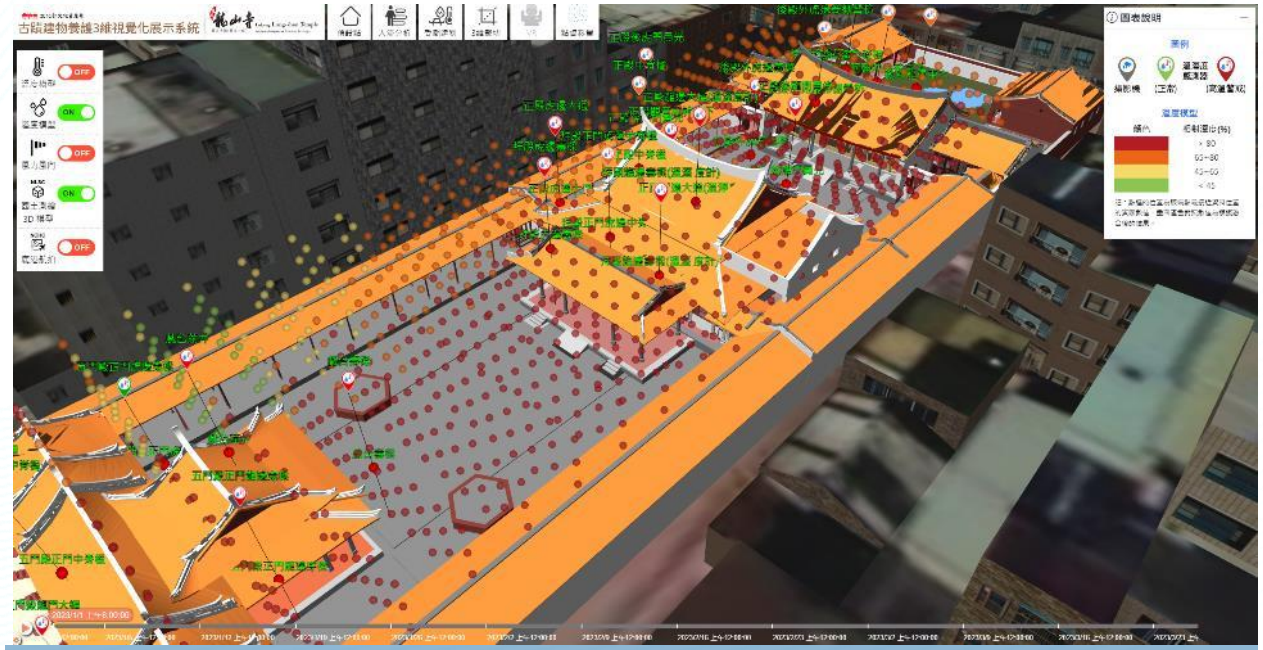


3D GIS Platform, Building Info Modeling (BIM) & Digital twin

- Integration of BIM and AI in public construction management.
  - **Taichung Dome** (台中巨蛋): Construction safety evaluation and planning, real-time safety regulation monitoring.
- Accelerate GIS adoption and development for public sector.
  - **Bureau of Cultural Heritage**: Digital twin of Lukang Longshan Temple
  - **Penghu county digital harbor**: 2024 Smart City Innovation Application Award



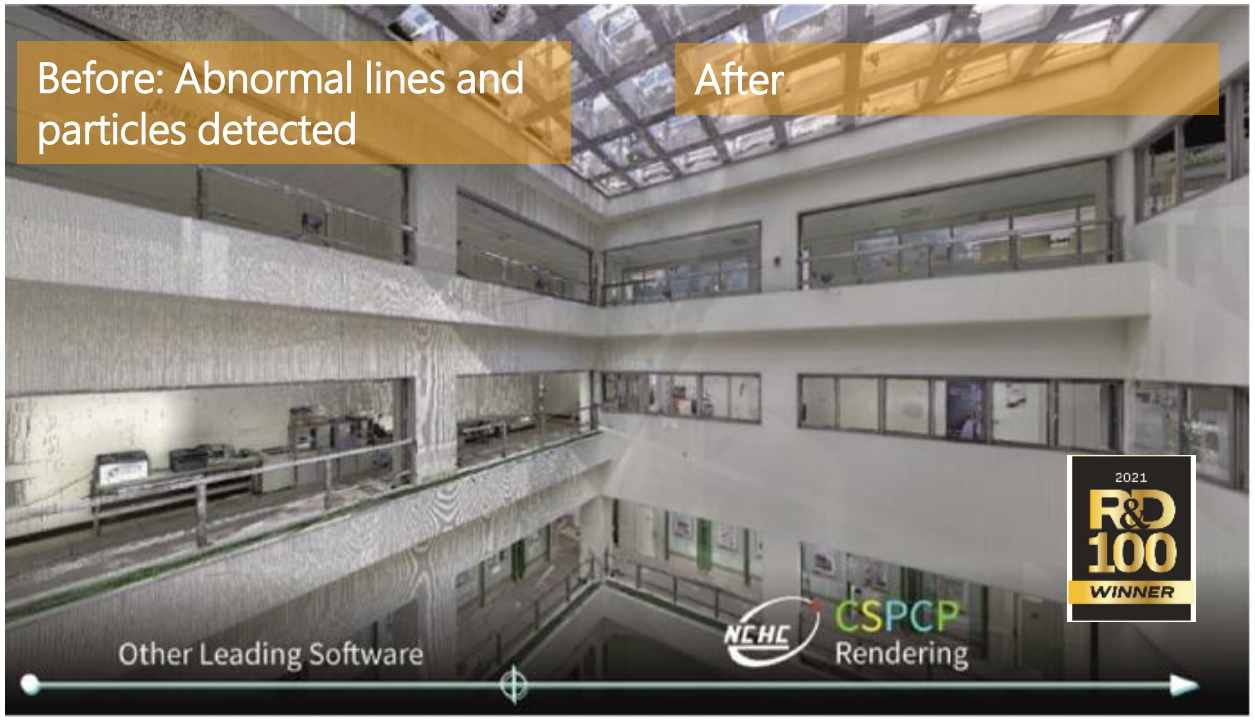
Taichung Dome: Construction Safety Management



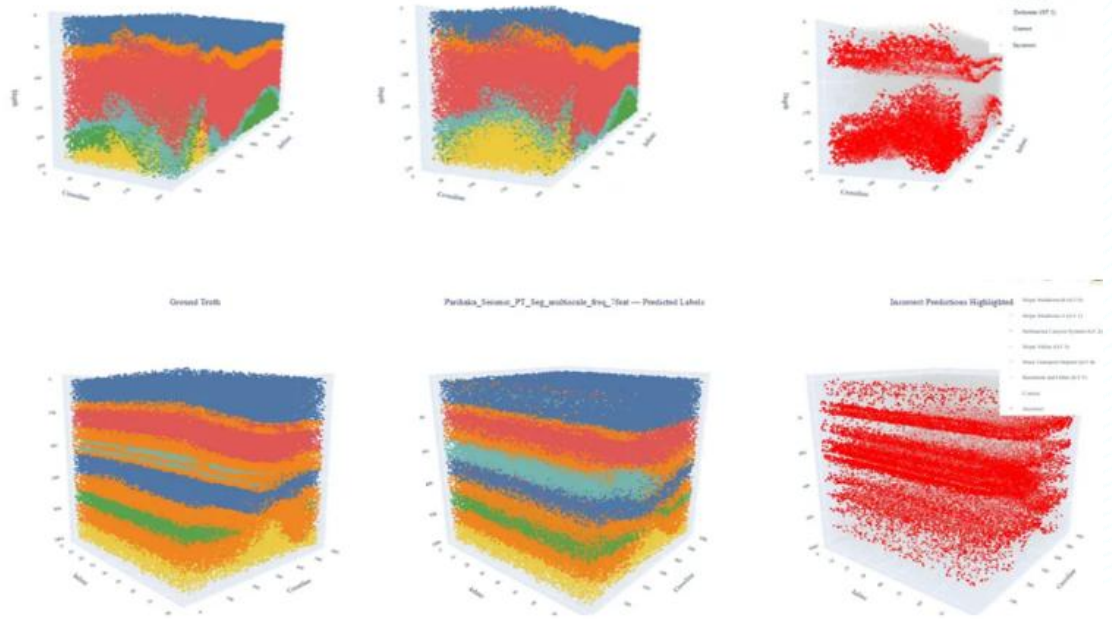
Digital twin of ancient monument model, with temperature and humidity monitored inside

Cloud-based smart point cloud processing

- Achieved 95%+ accuracy over public Oakland 3-D dataset.
- Recognized with 2021 R&D 100 Award and
  Platinum Award at 2023 Taiwan Innovation Expo Invention Competition.
- Innovative analysis of seismic data for geological carbon sequestration technologies



Point Cloud based AI seismic data interpretation



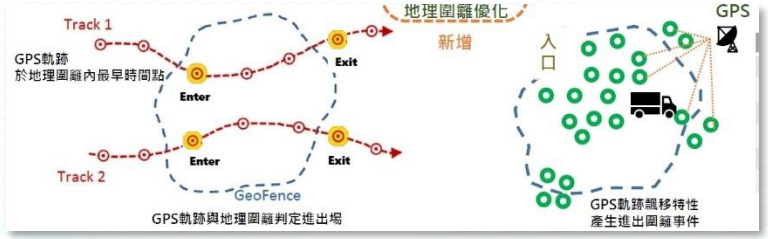
Core member: Ming-Jen Wang 王明仁

GIS for precision agriculture

Agriculture Spatial Information Collaborative Platform
of Ministry of Agriculture 農業空間資訊協作平台

- On-site crop image classification
  - Field surveys
  - 31 models/crops w/ sparse training sample
- Grape disease diagnostic
  - Classification of Grape Rust, Thrips infestation, and general pathologies.

- GPS tracking, LP recognition, and Geofencing
  - Trace pig transport vehicle for epidemic management
  - Transportation auditing



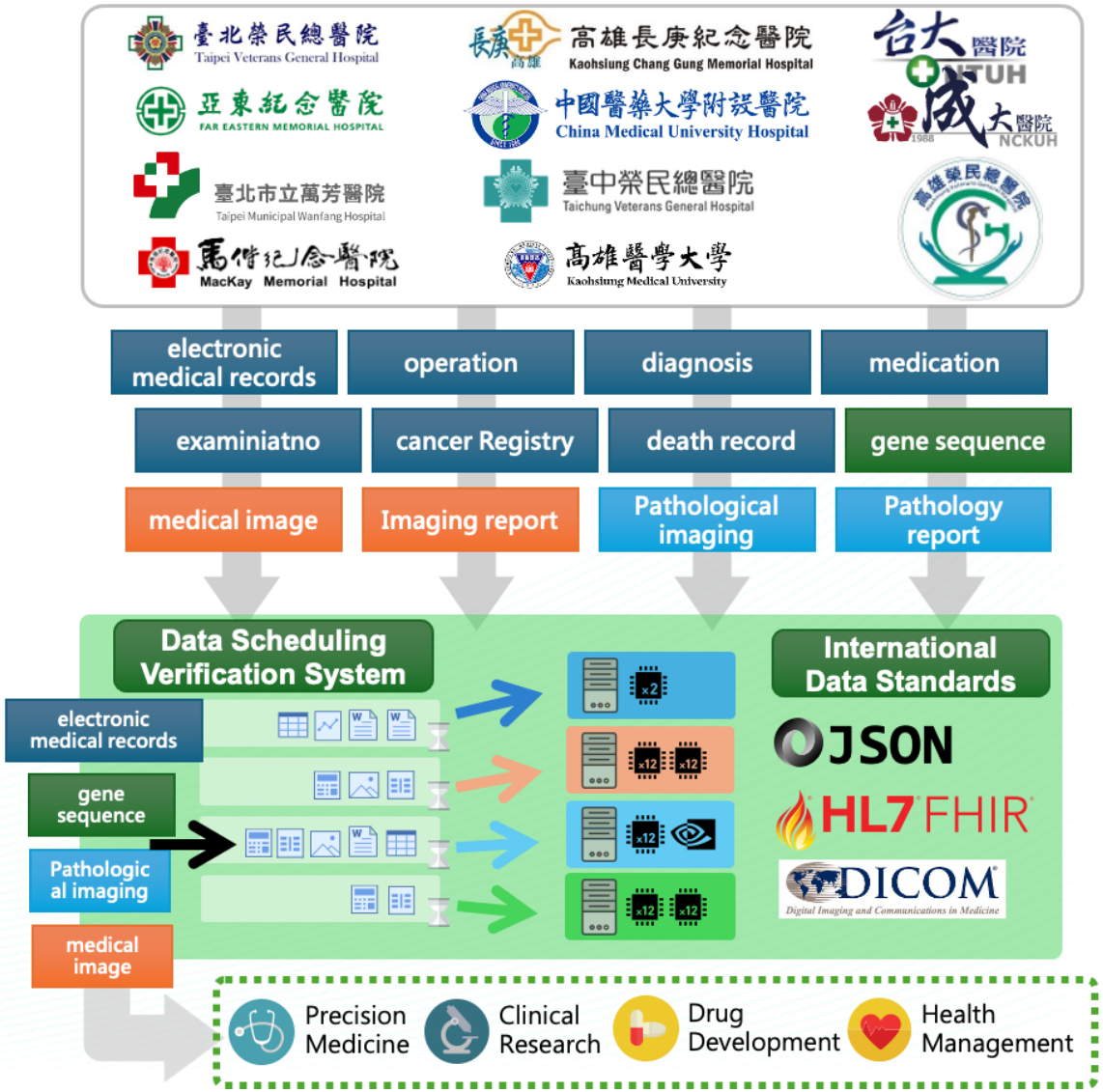
- Web/AI APIs integrated into MoA's Agri Field Survey Management (農業現地調管) and Transport Vehicle Audit System (運輸車輛查核管理)
- Collaboration with Agri. Tech. Res. Ins., NCKU, NTU

Core member: Yi-Liang Shih 施亦良

Sustainable health big data platform

- React to the national-wide goal to create real-world data ecosystem that facilitates data exchange and utilization for medical fields. (MoH, MoE, NSTC)
- Standardized data integration and high-volume interoperable storage services
  - Build data repositories for **EMR, medical imaging, genomics, and digital pathology** with automatic/manual quality checks.
  - Collaborated with 7 medical centers to standardize EMR formats and data exchange protocols under the Fast Healthcare Interoperability Resources (FHIR) framework.
  - ISO27001, 27017, 27018, and 27701 certifications.
- Long-term partnership with Taiwan Biobank

Core member: Yen-Jen Lin 林沿妊



Materials AI platform & Agentic workflow

The AI Agentic Workflow (Intelligence Layer)

1. Task Analysis & Intent Recognition

Identifies query intent and determines required capabilities (knowledge retrieval, computation, structured data access, or hybrid reasoning).

2. Task Decomposition & Modular Orchestration

Decomposes into sub-tasks and dispatches to appropriate modules: RAG Retrieval (Literature/ Knowledge Base); API Call (Calculation Modules); SQL DB Query

3. Evidence Integration & Logical Reasoning

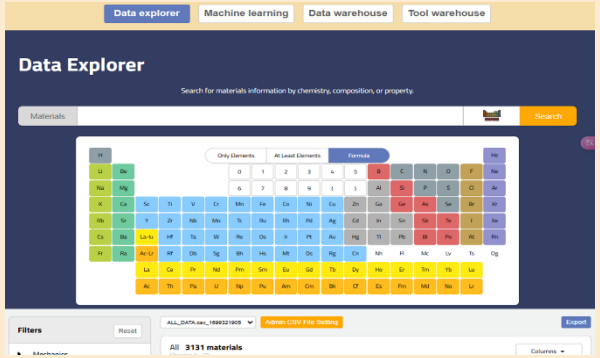
Aligns and synthesizes heterogeneous outputs, performs multi-step reasoning, and resolves cross-source inconsistencies.

4. Structured & Explainable Output Generation

Produces a structured, logically coherent, and comprehensive analysis report, via chatbot.

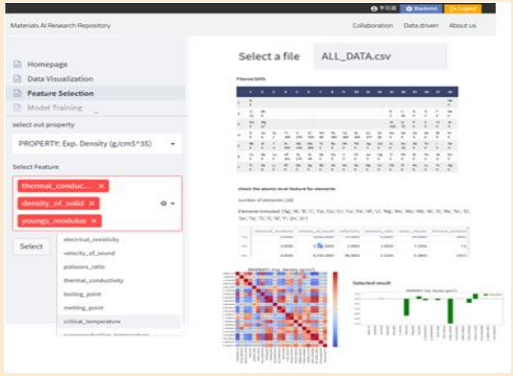
The Cloud Ecosystem (Infrastructure)

Data Explorer & Warehouse



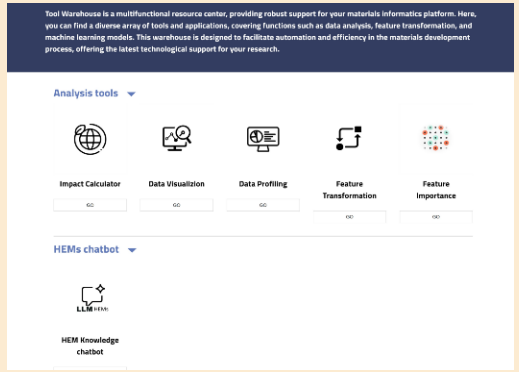
- SQL DB with multi-level IAM
- Retrieval and Filtering by Composition, Structure, and Properties

ML Environment



- No-code training and validation (Scikit-learn/AutoML)
- Feature engineering and Correlation analysis

Tool Warehouse



- Preprocessing, Visualization & External analysis programs
- Social impact calculator and LLM knowledge base

- "Materials Genome" toward interpretable/GenAI discovery. Eg., High-entropy alloy-based adv. structural materials.

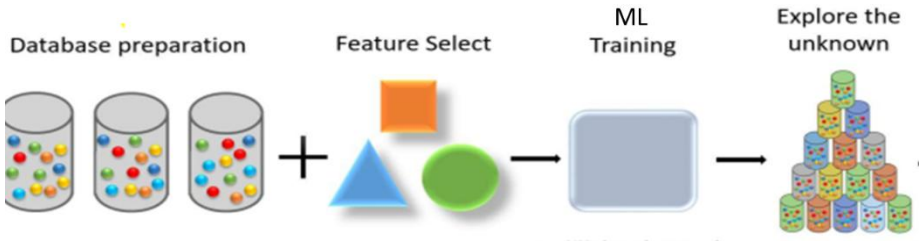
Core member: Wen-Jay Lee 李玟頡

AI for Semiconductors

Core members: Wen-Jay Lee, An-Cheng Yang, Nan-yow Chen, Kuan-Peng Chen

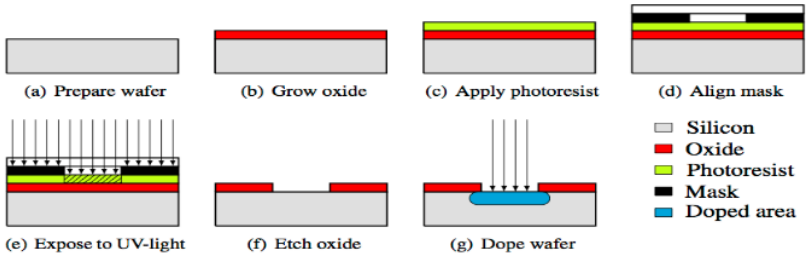
Data-driven exploration

- **Harder** high-entropy alloy
- ML to find additive molecular for Li battery



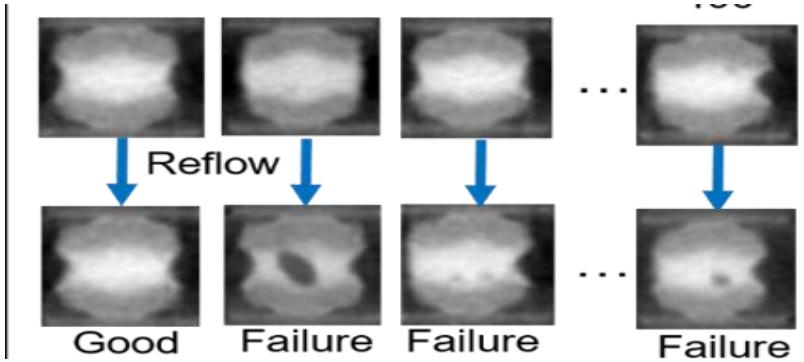
Process optimization

- Improve multistage manufacturing of **HEA and power device**



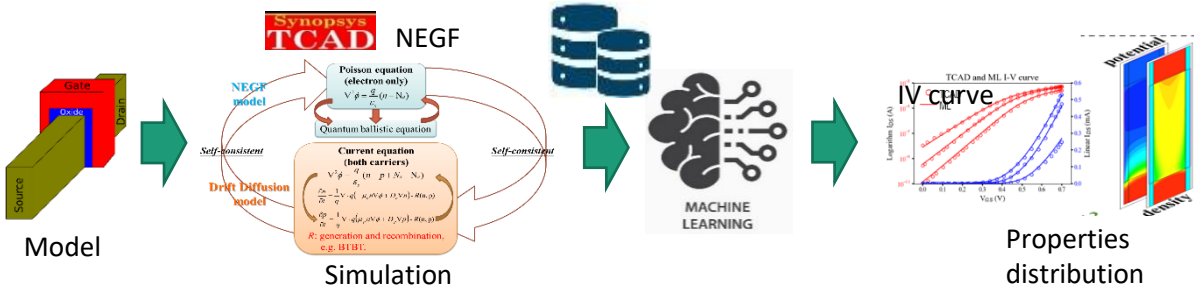
Reliability prediction

- Early detect 3D-IC structural weakness
- Rapid prediction of battery life



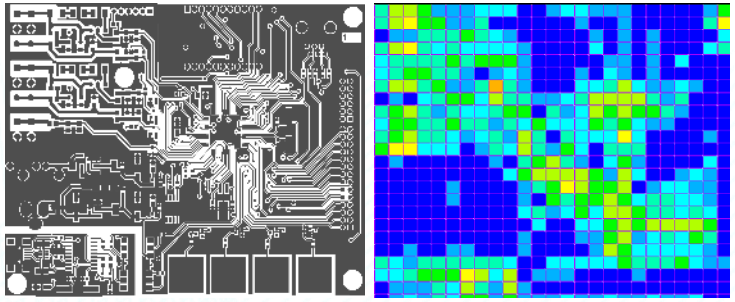
AI-aided design

- Data-driven/ Physical-informed, end-to-end deep-learning device simulation

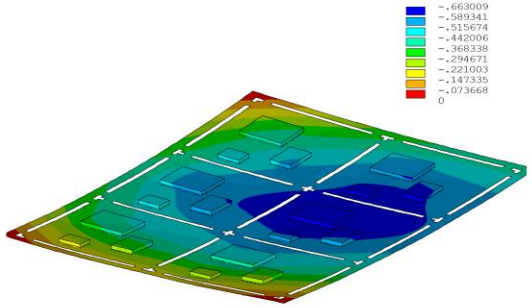


PCB warpage analysis & Cloud platform

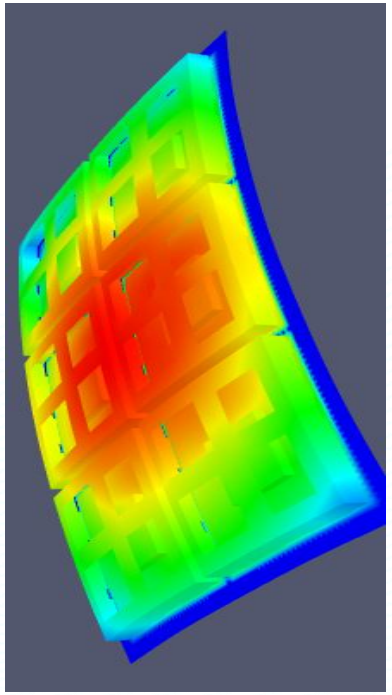
- Simplifies PCB warpage analysis and optimization parameter adjusting, automatically generate stress and deformation maps interactively.
- Reduce time for each trial from days/weeks → tens of minutes
- Key concern: Vendor data privacy

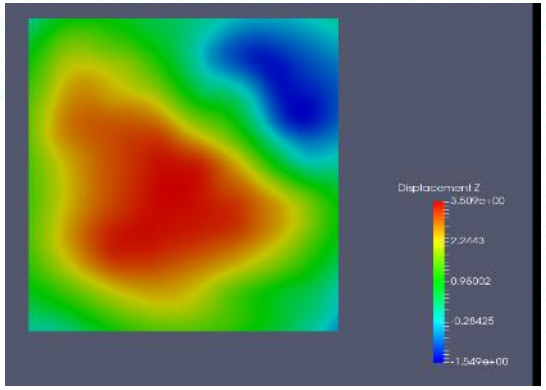


copper trace distribution



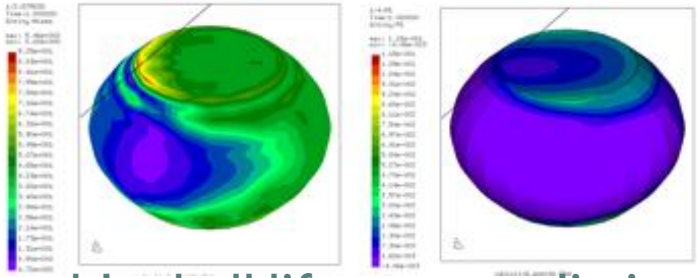
PCBA panel warping





PCB module warping

Stresses Plastic Strains

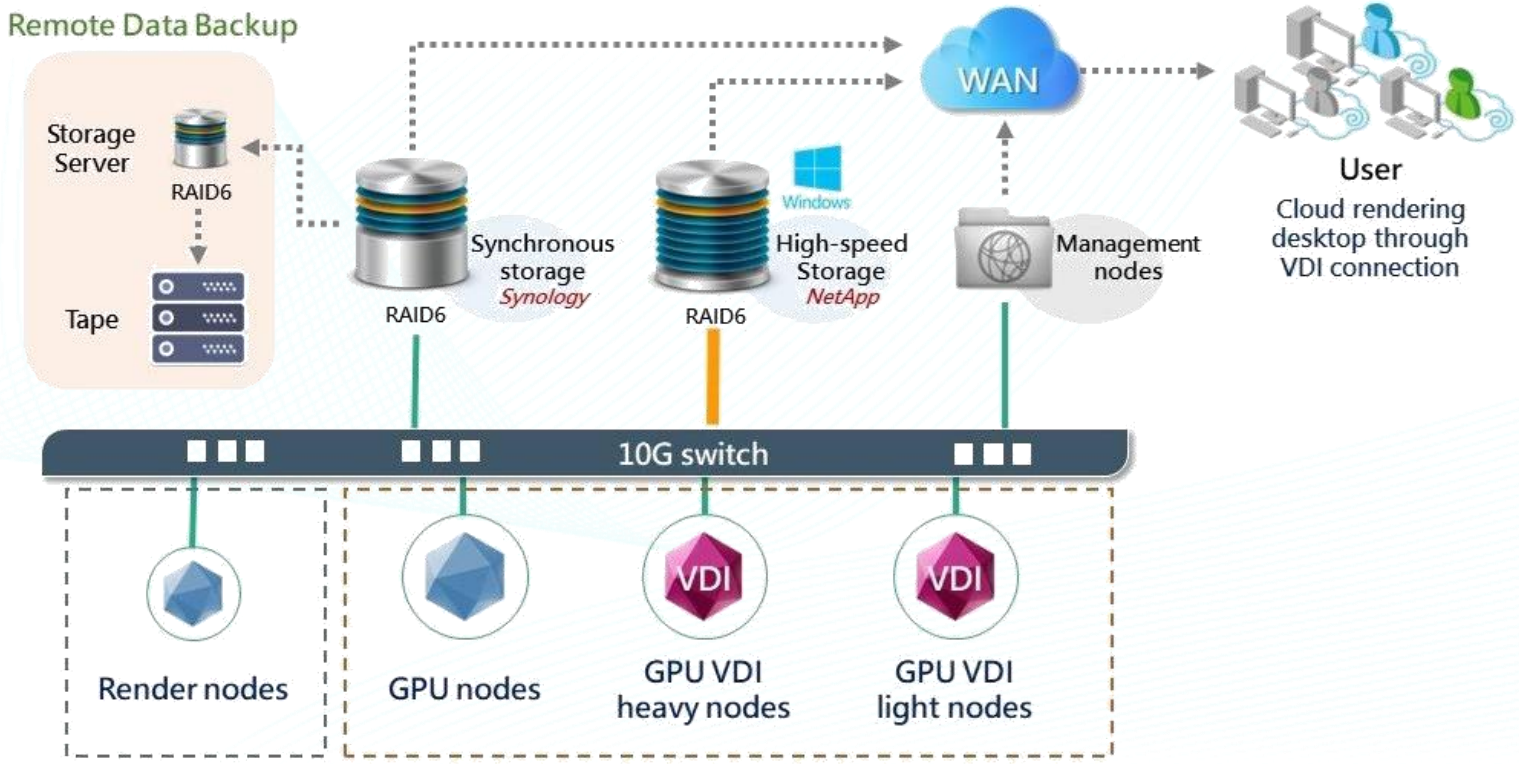


solder ball lifespan predictions

Core member: Ming-Hsiao Lee 李銘孝

Cloud GPU Render farm

- Launched in 2011 to promote Taiwanese animation film industry
- **Remote-GPU desktop** to speed up film production w/ **industrial rendering engines & management S/W**
- Develop special effect algorithm



Support iconic film productions

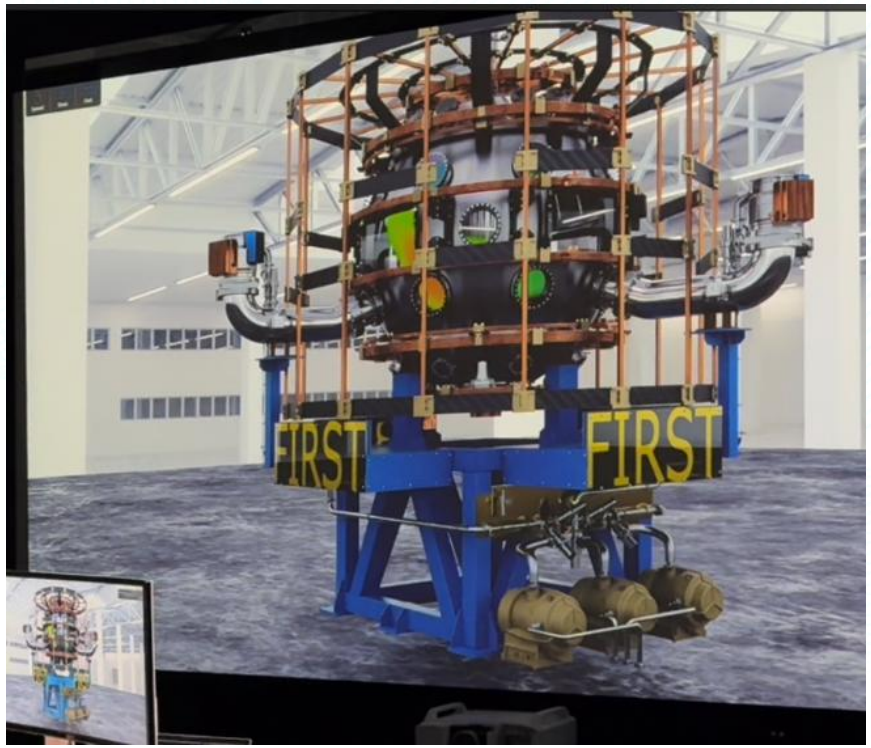
"Below Horizon"
special effect of fire

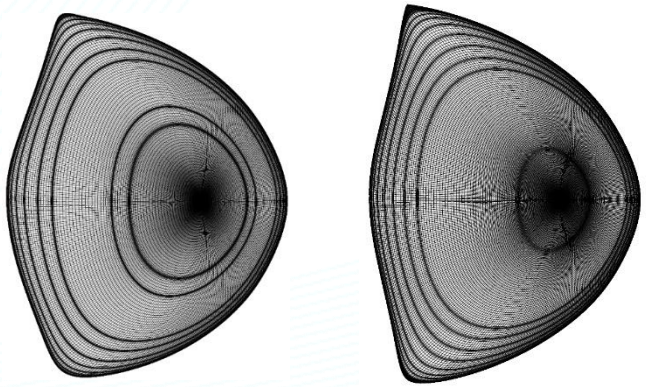
https://www.nchc.org.tw/Page?itemid=75&mid=139

Core member: Chuan-Lin Lai 賴傳霖

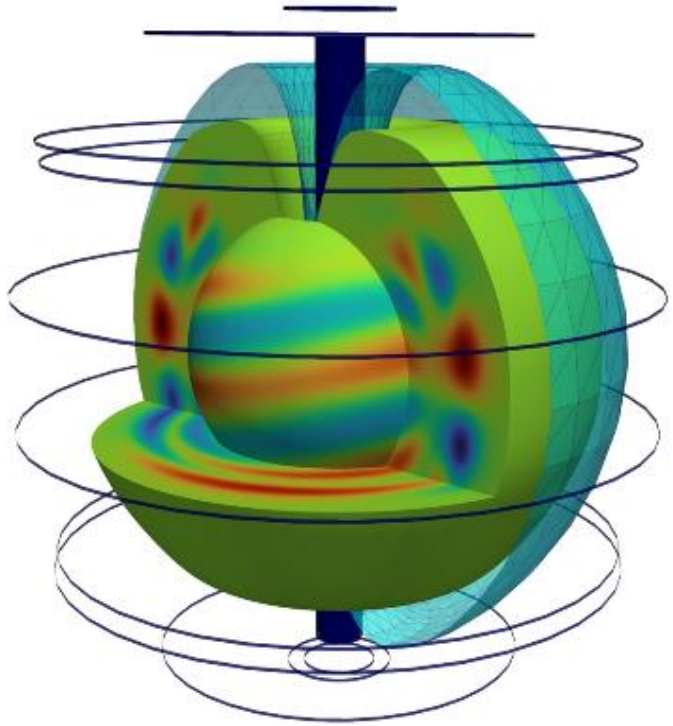
Nuclear fusion simulation for FIRST

- Support National Atomic Research Institute (NARI) for designing
  Formosa Integrated Research Spherical Tokamak (FIRST, eta. 2027)
- Optimize tokamak design to enhance simulation accuracy
- Strengthen real-time monitoring and control capabilities





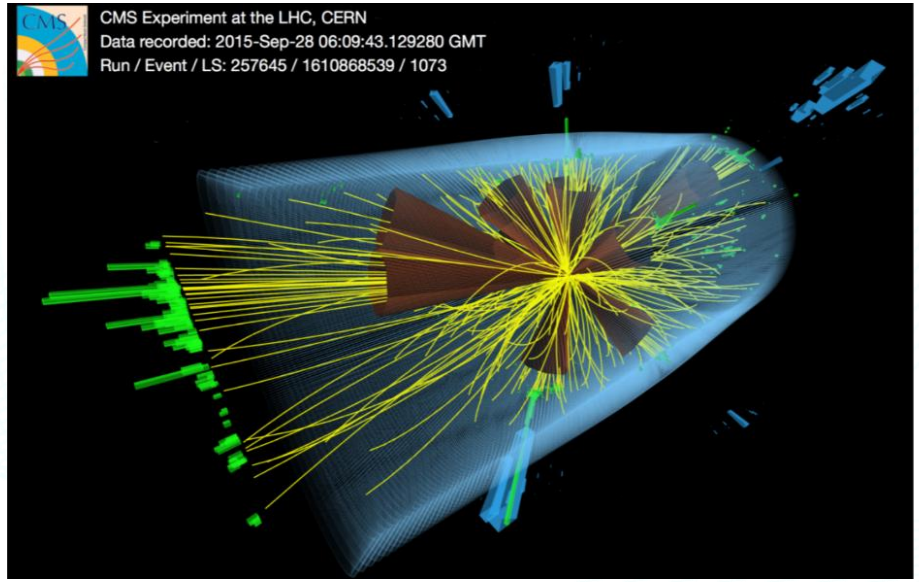
MHD stability in TOQ / EFIT format

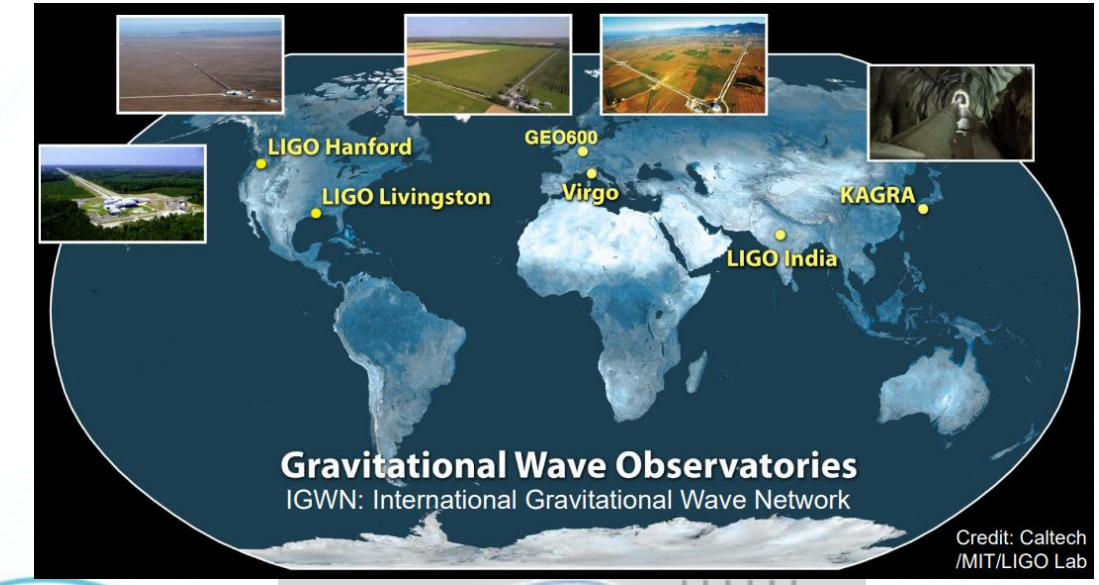


Core member: Tsung-Che Tsai 蔡宗哲

Scientific grid

- Support fundamental science with deliciated / opportunistic resource.
  - 2015- WLCG Tier-2 for LHC/**CMS**
  - 2022- Int. Gravitational Wave Network (IGWN: **KAGRA**/LIGO/Virgo) via OSG
- How HPC / Grid learn from each other ? Accelerator, Distributed storage, … ?





Sovereign AI and AI democratization

- TAIDE (Trustworthy AI Dialogue Engine) project since 2024 (7/13B model based on opensource).
- Taiwan AI RAP (Resilient and high-performance AI Platform)
  - GenAI services platform, from Infra and model fine-tune to workflow design, API service, and UI frontends...

- Applications & Pilot run customers:
  - Multilingual Indigenous Language AI/LLM Platform (16 tribes, 42 languages)

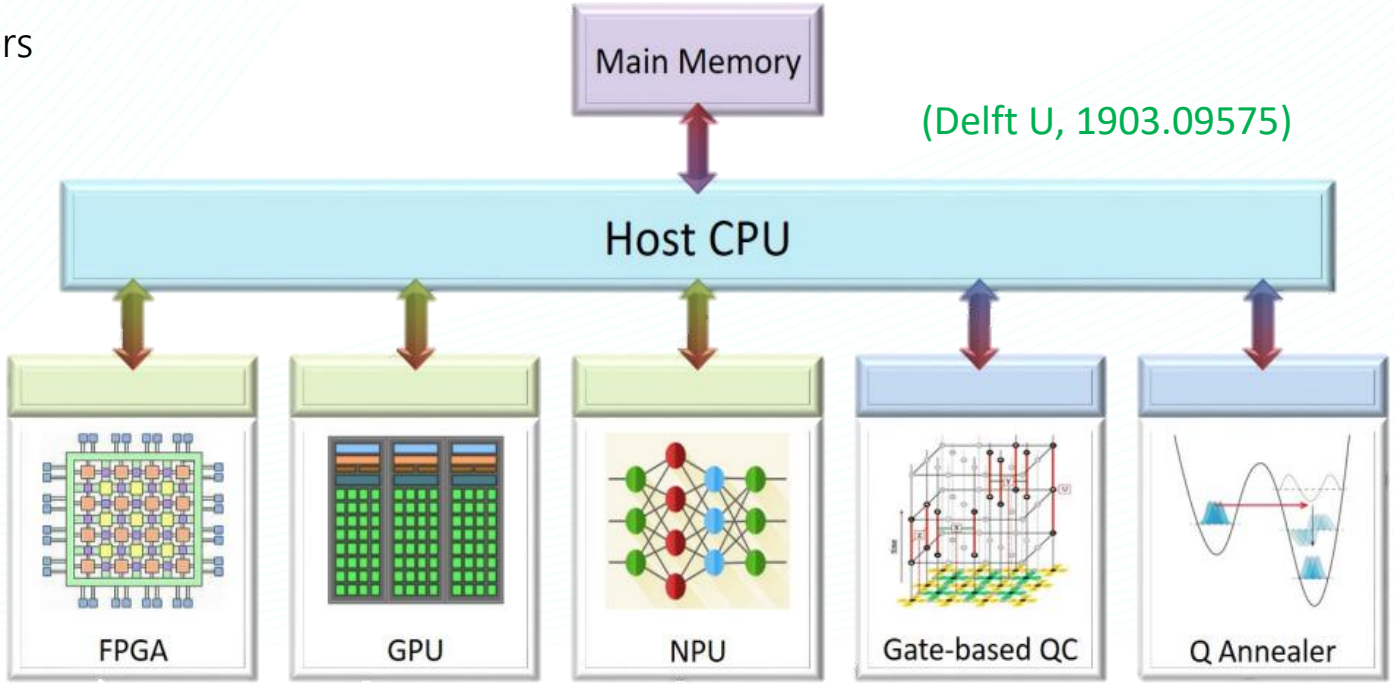
  - **Pedagogical** platform (NCU for traditional Chinese, 源智匯)
  - Storytelling: AI Visual Novel (中正大學)

  - **Industry** management (創鑫智慧 NeuChips)
  - Pig health & behavior monitoring platform (MoA)
  - **Solar power** monitoring & management (森崴能源)
  - Smart **shifting** (高雄榮總 KSVG Hospital)

  - Smart **Quality Assurance Manual** for medical materials (弘世生技)
  - LLM/RAG-based **knowledge hub** system, **chatbots** (MoDA, TASA, CDNA of Sinica, ..)
  - LLM-based image search, ASR & translation, ... (慧演智能 Claireye, 環球睿視, ...)
  - AI customer service (大橡科技,環資國際, TW Biobank...)
  - myPDA infra service for SME's agentic AI deployment (NYMCTU)
  - ...

Quantum computing & HPC

- New computing paradigm, rethink information processing and rebuild toolchains.
- On the other hand, QC as accelerator, fit naturally in heterogenous HPC.
- They're challenging HPC app: Circuit/Quantum simulator, EDA & quantum chip design.
- Most Q algorithms now is hybrid, need to cooperate with classical computers.
  - Hybrid Quantum-Classical Computer to be assembled in Tainan IDC 2026
  - "Quantum hub" collaborated with Lab/ Vendors



(Delft U, 1903.09575)

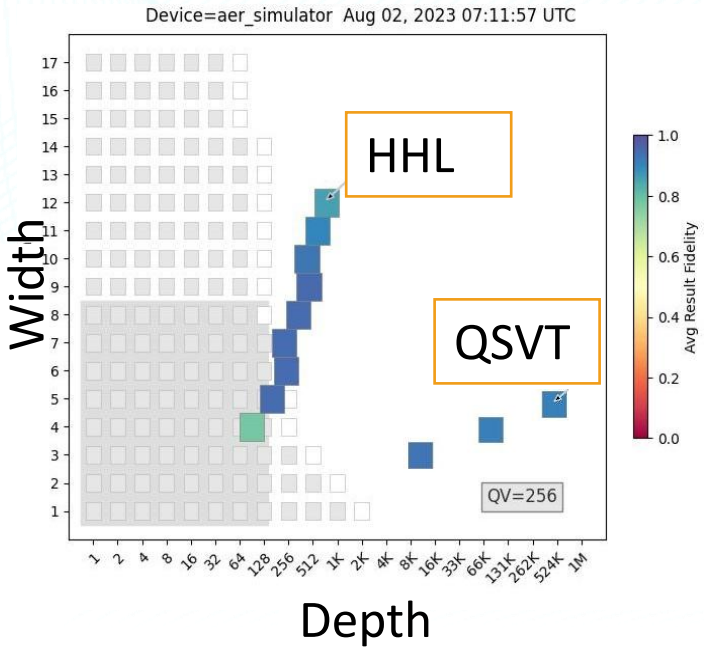
Some popular QC modality in 2026+

Modality	Phy. Qubits	1q err (%)	2q err (%)	T1/T2	Gate time	Features
Superconducting (IBM/ Google)	120 – 1080	0.007 – 0.01	0.06 – 0.4	O(100 ns)	O(10 ns)	Fixed-freq/Flux-tunable transmons. Heavy-hex and Square-lattice topologies for QEC.
Superconducting (IQM)	20 – 150+	< 0.02	< 0.07			Star/Crystal Topologies; Tunable couplers (2508.16437)
Superconducting (Fujitsu)	64 – 1024	< 0.01	< 0.1			Vertical 3D Connection; STAR architecture (Space-Time efficient Analog Rotation, 2408.14929) to reduce gates;
Trapped Ion (IonQ, Qudora)	36 – 100	< 0.02	< 0.4	**O(hours-min)**	O(10-100us)	Algorithmic qubits (#AQ) as metric; Microwave-controlled ions (Oxford Ionics); Laser-driven gates;
Trapped Ion (Quantinuum)	96 – 1000	-	**0.01 – 0.05**			QCCD (Quantum Charge-Coupled Device) allows ions physically moved (2003.01293). All2all interaction reduce circuit depth. TKET toolkit.
Neutral Atom (QuEra, Pasqal)	**256 – 3k**	< 0.03	< 0.5	O(sec)	O(us – ms)	Atoms as perfect qubits; Rydberg blockade; Optical tweezers; Dynamic topology; Analog/Hybrid mode. (2304.05420)
Photonics (Quandela)	6-24	< 0.4	< 1	Loss-based	O(ps)	Quantum-dot single-photon sources (95%+ photon indistinguishability); Full-stack QML software;
Silicon Spin	12 – 50	0.01 – 0.1	0.1 – 1.0	O(ms - sec)	O(10-100 ns)	Quantum Dots; 300mm CMOS Fab integration; P-31 donors or hole spins in Silicon.

On-going studies

Simulator & Benchmark

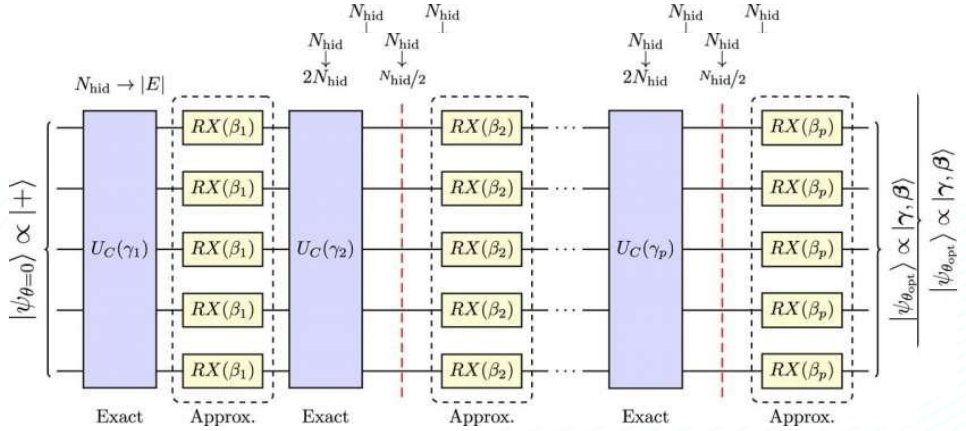
- Circuit / TensorNetwork sim
  - 43 qubits full state vector sim on F1
  - O(1000)+ qubits MPS-TN sim
- Application-level benchmark



Depth-width tradeoff of quantum linear problem

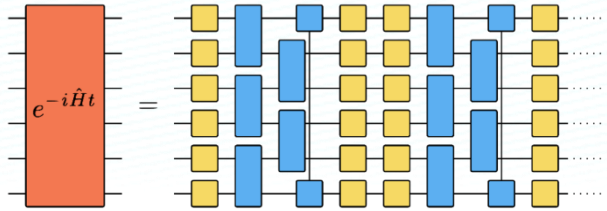
Machine learning & Optimization

- Industrial optimization via QUBO, QAOA.
- Neuron network via parameterized, variational quantum circuit.
- Quantum analogue of CNN, Graph network, LSTM, …



Quantum Simulation

- Many-body effects of quantum dynamics

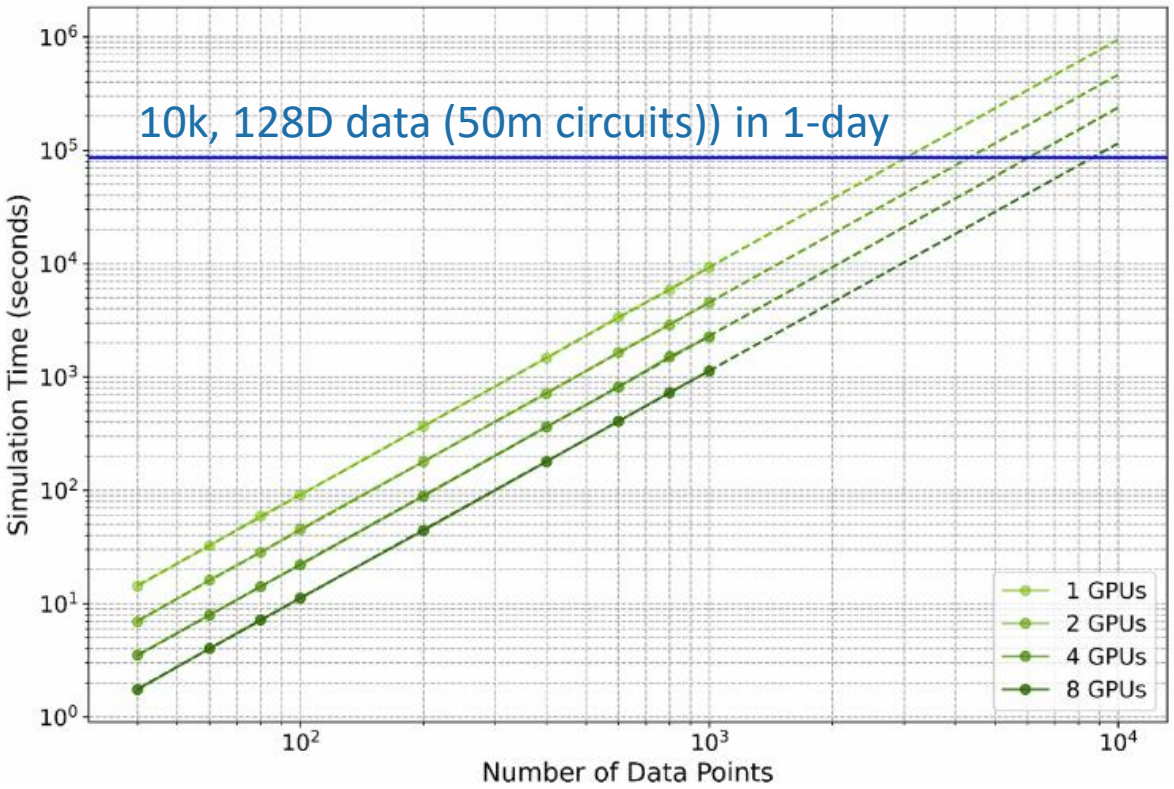


Scalable kernel-based QSVM via Tensor-Network

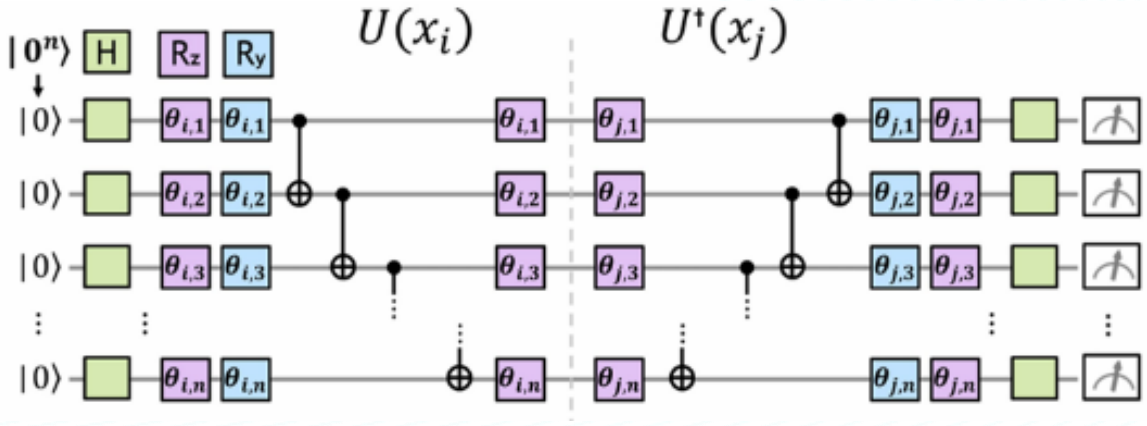
- Kernel functions in SVM → Overlap of quantum features (Feature dimension = #qubit)

$$k(x, x') \rightarrow \langle \psi(x) | \psi(x') \rangle$$

- Train N samples → N^2 circuits; Inference M samples → NM circuits to compute.
- Linear time scaling over N



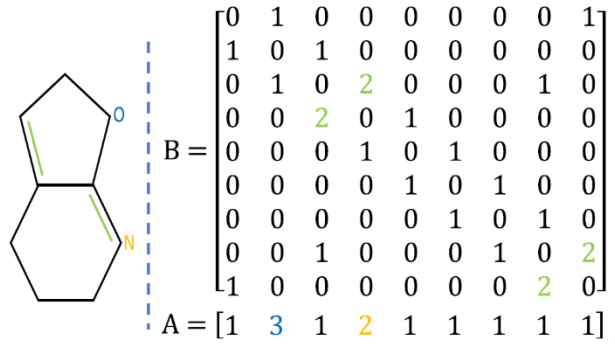
Machine Learning: Sci. Tech. **6** (2025)
w/ TY Li, NY Chen, AC Yang

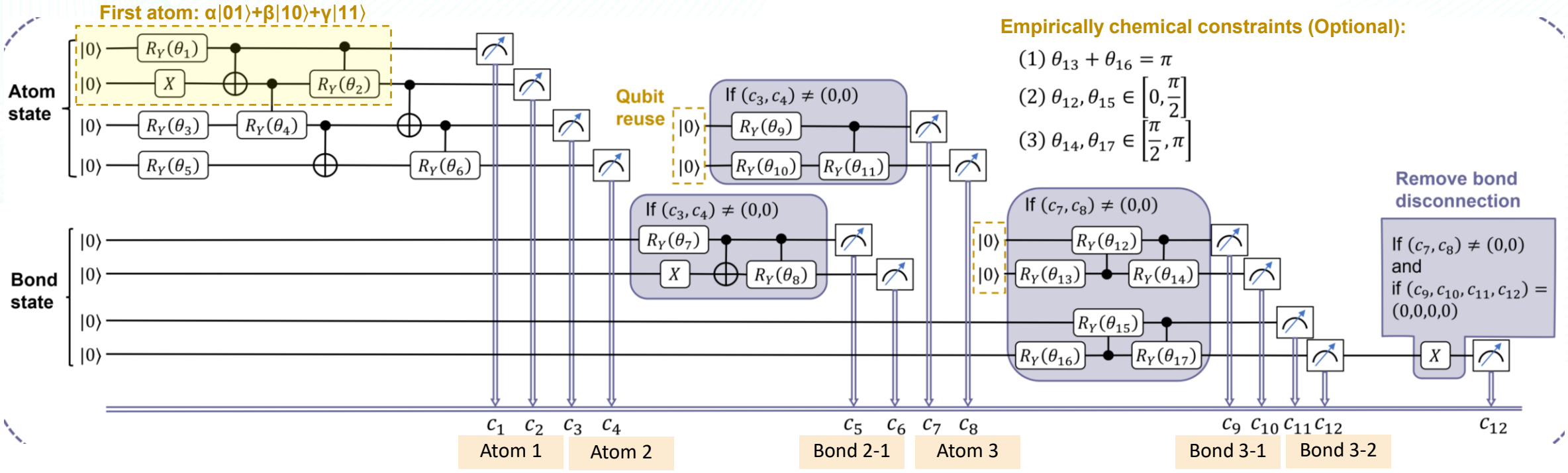


Quantum Molecular Generation

"Exploring Chemical Space with Chemistry-Inspired Dynamic Quantum Circuits in the NISQ Era", J Chemical Theory and Comp (2025)

- Domain knowledge-driven, high chemical validity gen model
  - parameter efficiency: 134 parameters enumerate 9-heavy atom molecular (C, N, O).
  - Tailored generation by constraining parameters & Bayesian optimization.
- Dynamic circuit to reduce qubit overhead, $O(N^2) \rightarrow O(N)$ for N-atom.
  - Atom types: $\{|00\rangle_{\text{None}} \ |01\rangle_{\text{C}} \ |10\rangle_{\text{N}} \ |11\rangle_{\text{O}}\}^{\text{N}}$
  - Bond types: $\{|00\rangle_{\text{None}} \ |01\rangle_{\text{Single}} |10\rangle_{\text{Double}} \ |11\rangle_{\text{Triple}}\}^{C_2^N}$
  - 90 → **20** qubit for 9 atoms (C,N,O)



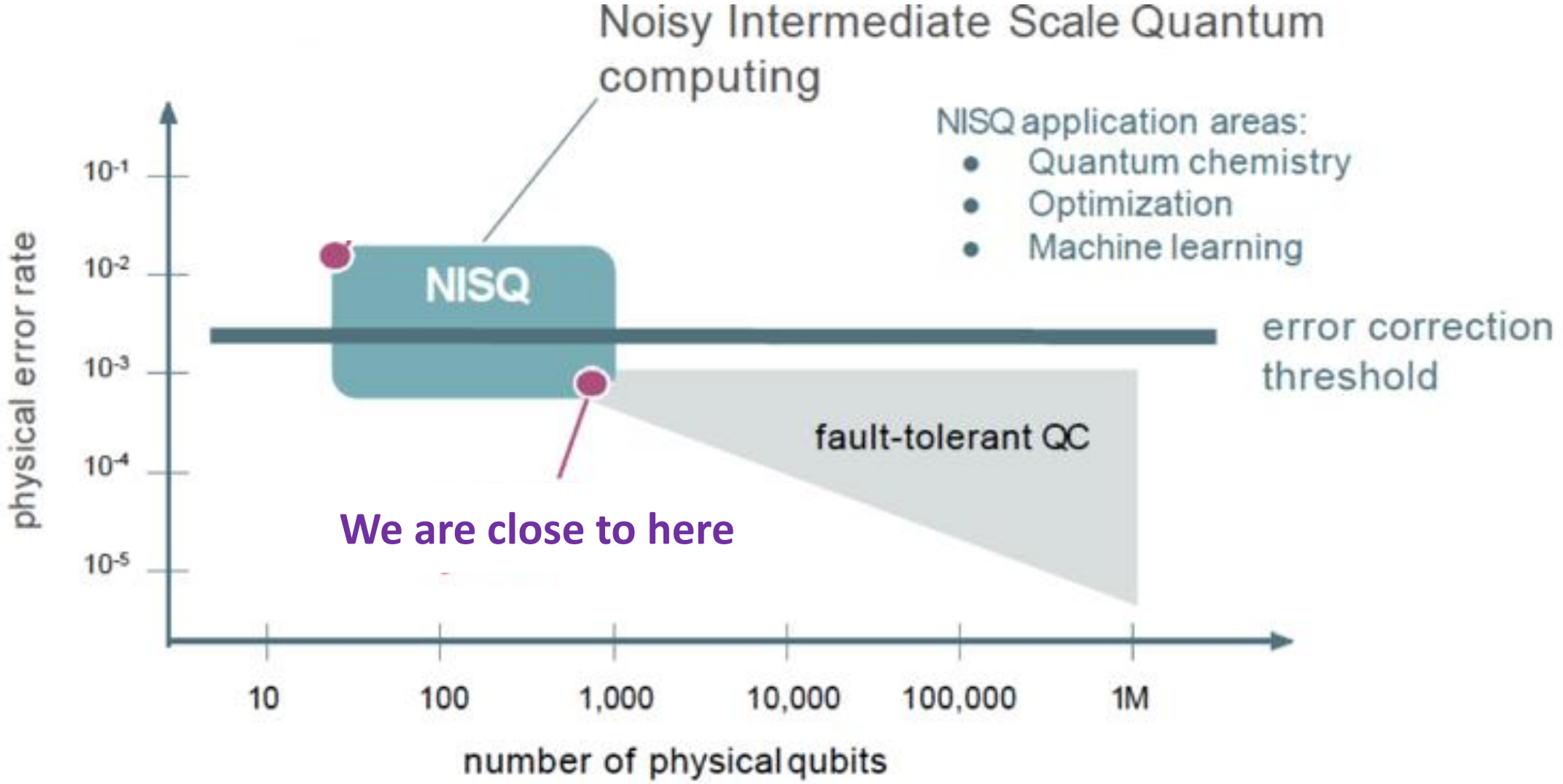


Summary

- NCHC as the service provider of supercomputing and the TWAREN backbone.
- Diverse research and platform services response to communities with blurring boundary of HPC and Cloud
- Preparing for quantum:
  - We've focused on algorithm, application, and software toolchains.
  - Work on hybrid quantum-classical computing integrated with HPC (in Tainan IDC).
  - Quantum Hub to bridge technology gaps through collaboration.

~ Thank you ~

NISQ



[1801.00862] Quantum Computing in the NISQ era and beyond by John Preskill

iService SSO portal

台灣杉二號 TAIWANIA 2

TWCC 臺灣AI雲 TAIWAN COMPUTING CLOUD

台灣杉三號 TAIWANIA 3

Forerunner1 創進一號

晶創25 NANO 5

晶創26 NANO 4

TAIWAN AI RAP

LIONS國網生科雲 Life science Informatics ON-cloud Services

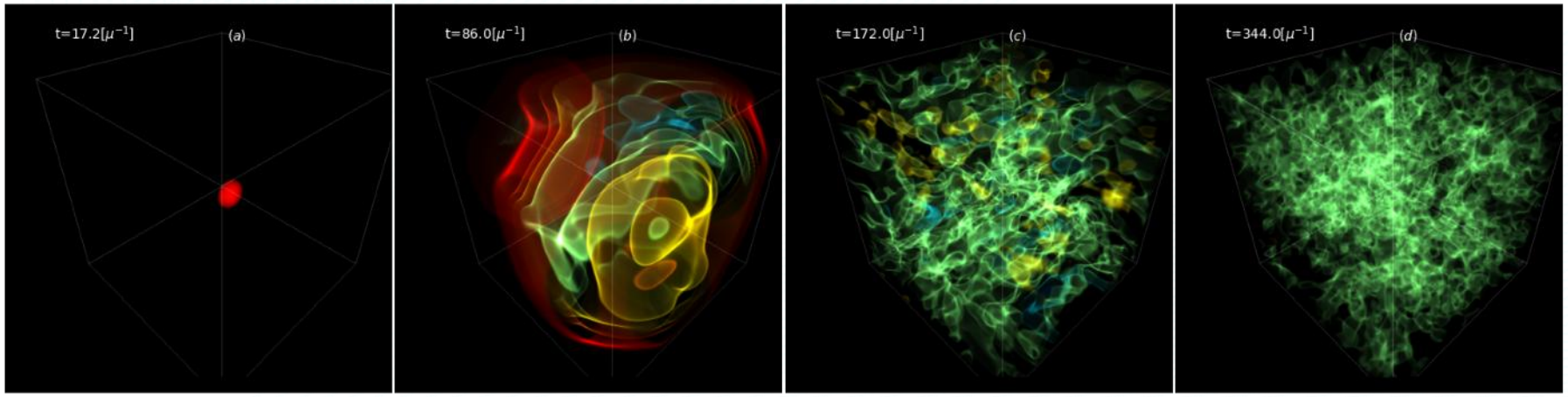
算圖農場 NCHC Render Farm

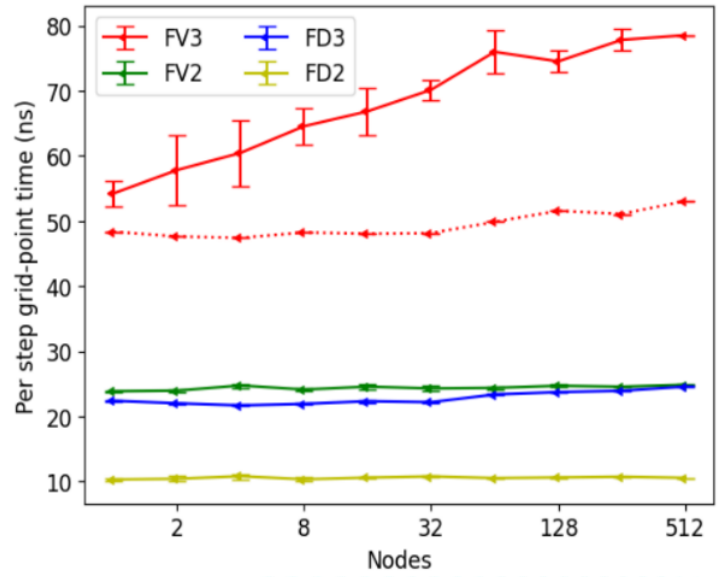
SensiMesh 機敏雲

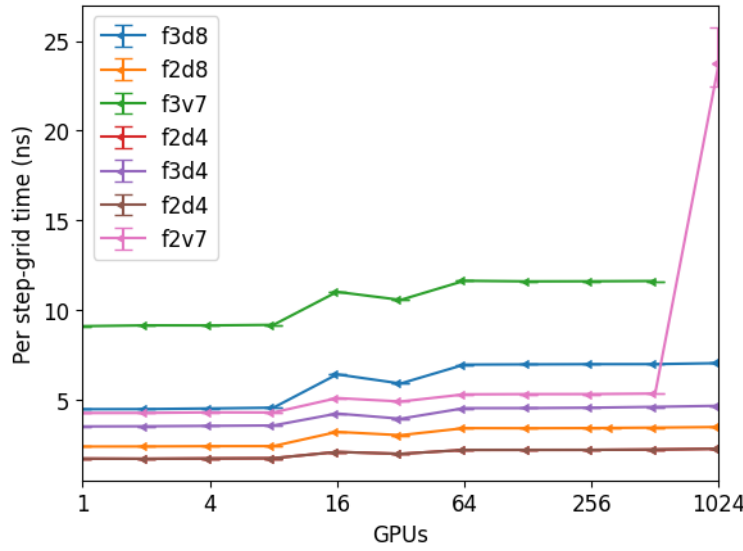
- Frontend & backend for project application, IAM, accounting, wallet management, resource purchasing, quota request, usage analytics, etc…

Collective neutrino oscillation simulation

- Precision simulation of neutrino transport **quantum kinetic equations (QKEs)**
- Developed **classical surrogate models** to bridge microscopic effects with macroscopic fluid dynamics.
- Collaborated with Meng-Ru Wu's group (ASIoP), PRL **134** (2025)
- Large-scale scalability on Forerunner-1 and Nano4







Research Service & Platform

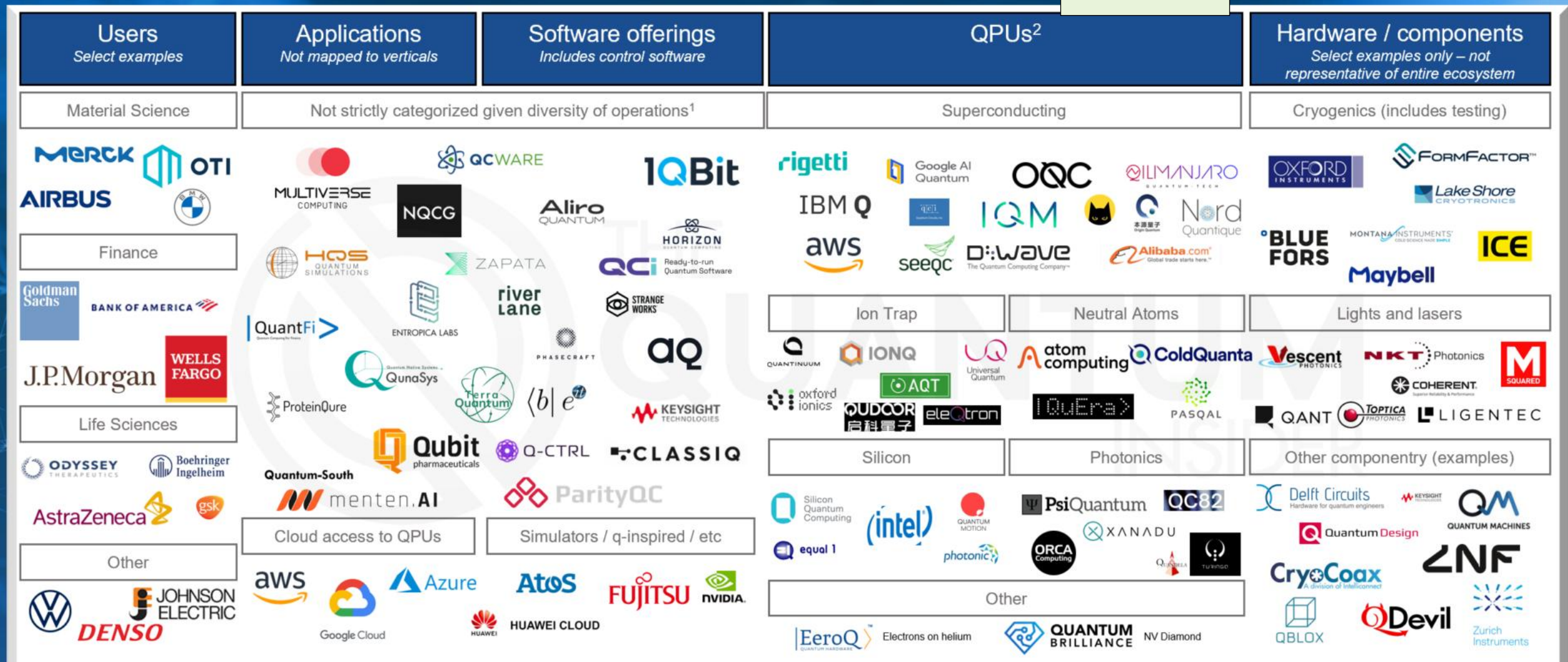
- TCCIP (Taiwan Climate Change Projection Information) Adaptation Knowledge Platform
  臺灣氣候變遷推估資訊與調適知識平台
- 3D GIS Platform, Smart City & Environmental disaster prevention & relief
- Ocean negative carbon research platform: from seismic reflection data portal to CCS simulation
- Sustainable Health Big Data Platform (健康大數據) & Taiwan biobank (台灣人體生物資料庫)
- GIS for precision agriculture
- Material platform (adv structural materials based on high-entropy alloy) & Semiconductor research
- PCB warpage analysis & Cloud platform
- Render farm (算圖農場)
- Nuclear fusion simulation for FIRST
- WLCG/IGWN Grid computing
- Taiwan AI RAP - Sovereign AI and AI democratization, Multilingual Indigenous Language AI/LLM
- Quantum computing…

~ Thank you ~

Quantum Computing Market Map

2022 May

Non exhaustive and in no particular order. Excludes details on control systems, assembly languages, circuit design, etc.

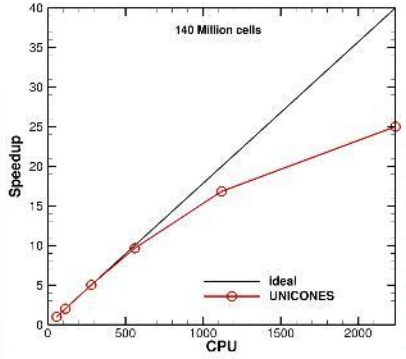


[1] Software offerings can be further classified into SDKs, firmware / enablers, algorithms / applications, simulators etc. but many companies are offering a mixture across the stack

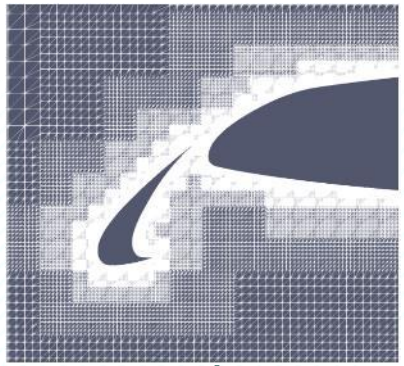
[2] Many QPU providers are offering full stack services (e.g. Pasqal acquired Qu&Co, Quantinuum was originally CQC prior to merger with HQS, etc.

High-accuracy simulation platform

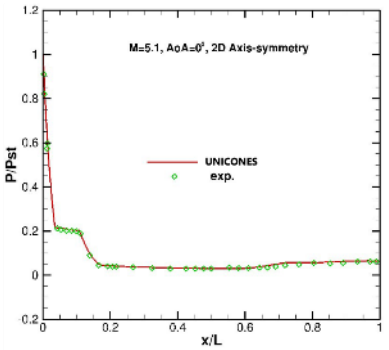
- High-fidelity numerical methods (CE/SE method)
- High-efficiency parallel computing (up to 84% for over 1000 CPUs)
- Automatic mesh generation (Octree meshes)

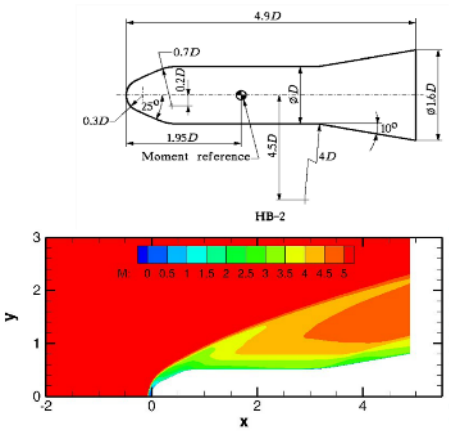


Parallel efficiency

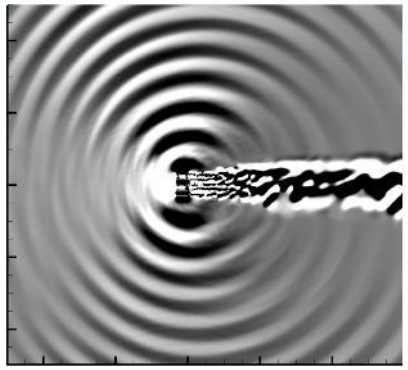


Octree mesh generation

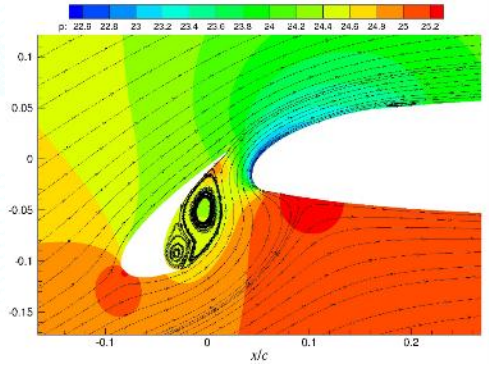


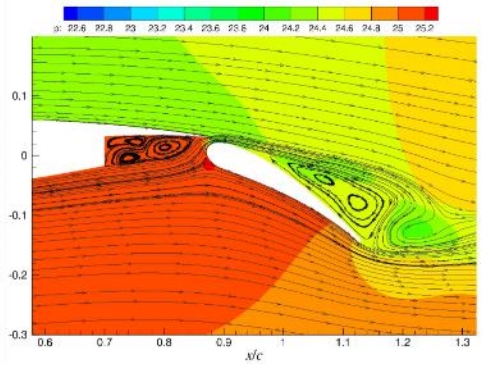


Hypersonic flow simulation



Acoustic wave simulation

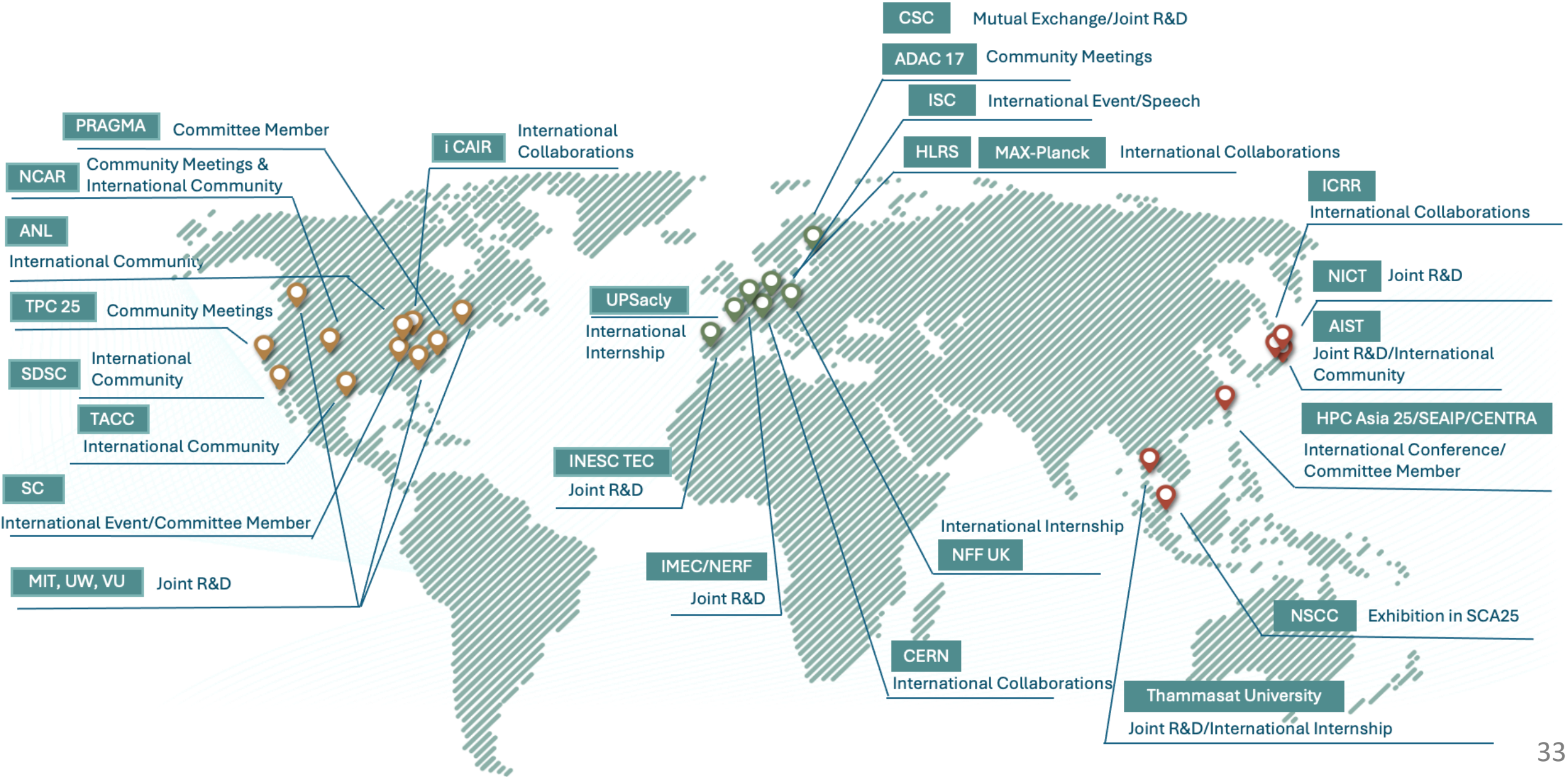




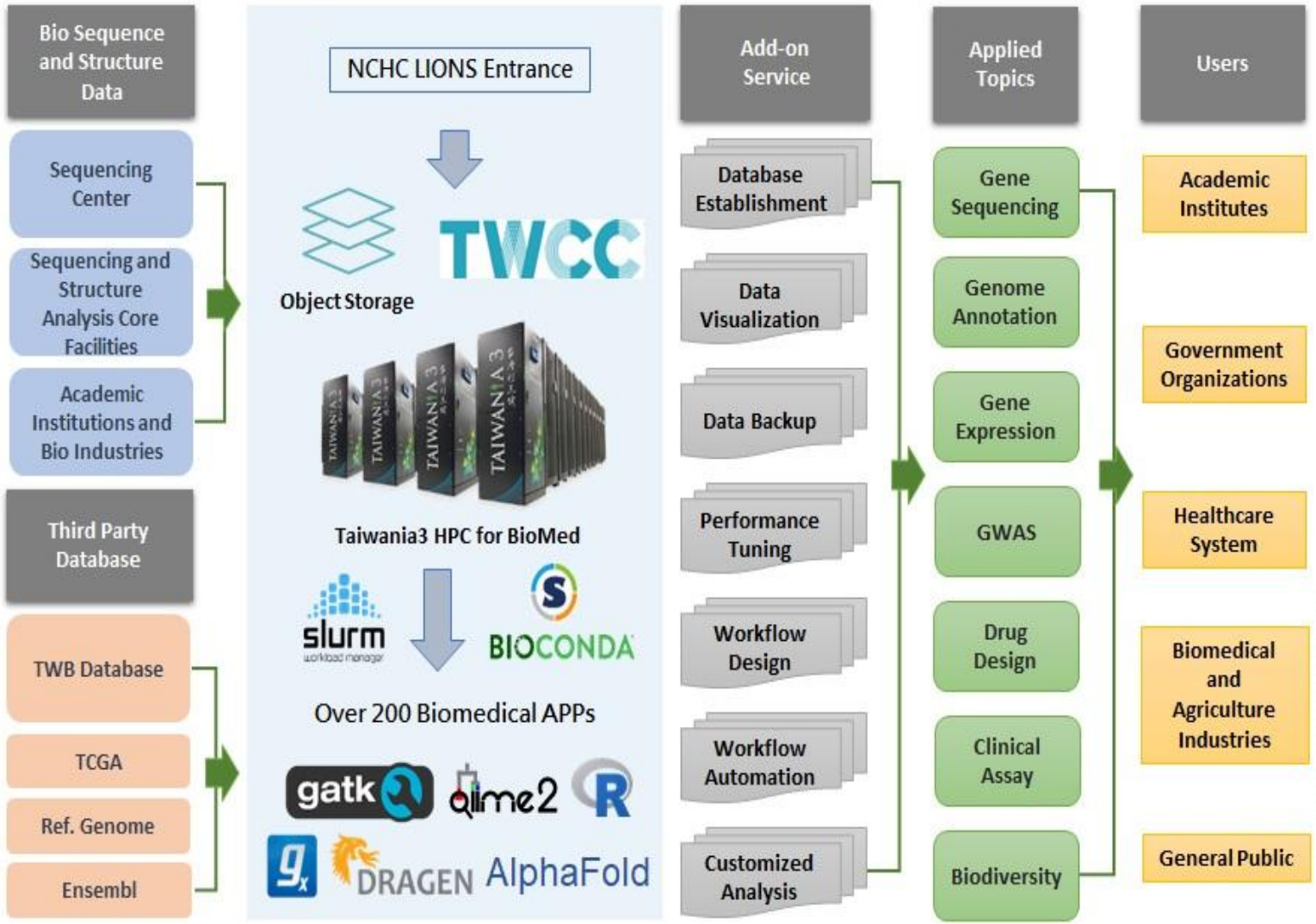
Complex fluid structure

Slides from Fang-An Kuo 郭芳安

International Collaboration (Y2024-2025)



Life Science Cloud



- Trustworthy environment for large group users of biomedical data
- Provide libraries, software, and packages for analysis and computing in life science, medicine, and agriculture.
- Optimized to fit characteristics of biological data to improve computing services.

Computing Power Plan

2024-2028

Taiwan Chip-based Industrial Innovation Program

To support this program, NCHC will develop a shared heterogeneous architecture supercomputer for general-purpose AI, large-scale scientific research, and quantum computing, creating a user-friendly cloud service platform to foster application efficiency.

2024

0.8 MW
(16 PF) GPU
- 400+ GPUs
- 10 PB storage
- InfiniBand 200Gbps
- PUE <1.35

2025

4.3 MW
(100 PF) GPU
- 1680+ GPUs
- 25 PB storage
- InfiniBand 200Gbps
- PUE <1.3

2026

3.6 MW
(80 PF) GPU+CPU
- 1200+ GPUs
- 20 PB storage
- InfiniBand 400Gbps
- PUE <1.27

2027

2 MW
(35 PF) GPU+CPU
- 520+ GPUs
- 10 PB storage
- InfiniBand 400Gbps
- PUE <1.25

2028

2.7 MW
(49 PF) GPU+CPU+Quantu
- 700+ GPUs
- 10 PB storage
- InfiniBand 800Gbps
- PUE <1.25

Total 13.4 MW (280 PF)

2029

3 MW
(65 PF) GPU+CPU
- 1020+ GPUs
- 20 PB storage
- InfiniBand 800Gbps
- PUE <1.25

Total 9.6 MW (200 PF)

2.9 MW
(60 PF) GPU+CPU
- 1000+ GPUs
- 15 PB storage
- InfiniBand 400Gbps
- PUE <1.25

3.7 MW
(75 PF) GPU+CPU
- 1260+ GPUs
- 25 PB storage
- InfiniBand 800Gbps
- PUE <1.25

2027-2029

New Silicon Valley in southern Taiwan Project

The National Science and Technology Council announced the launch of a new national program in August 2024, planning to invest in the development of Taiwan's own artificial intelligence platform over the next five years to promote the smart technology industry ecosystem in southern Taiwan. The plan will establish 200 PF of computing power and increase the nation's overall computing power to 480 PF.

NCHC milestones -- Network & Computing

1991
Found

2003
Under
NARLabs

2004
TWAREN
20 G

2011
ALPS
177 TF

2016
TWAREN
200 G

2017
Twnia
1.33 PF

2018
Twnia-2
9 PF (GPU)

2020
Twnia-3
2.7 PF

2022
Formosa
Open eXchange

2023
Forerunner
3.5 PF

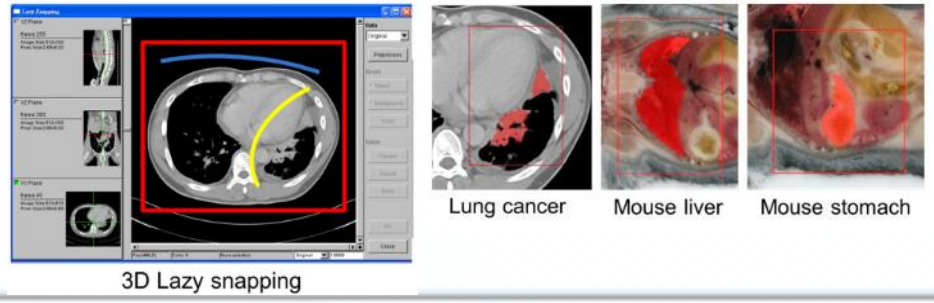
2026
Nano4
80 PF

Scientific Visualization

- Total solution from data processing to visualization and interactive browsing in VR
- In-house software: MiiL - Medical image illustrator,
  vvViewer - Visualization & interactive media lab's VR Viewer

Medical image processing and browsing

【 MiiL 】 image labeling and segmentation



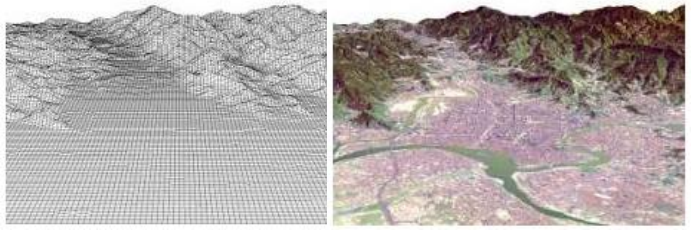
3D Lazy snapping

【 vvViewer 】 VR browsing

CT, MRI data processed by MiiL, viewed in vvViewer.

GIS

Satellite, aerial photo, and 3D terrain data, for disaster prevention decision support, and facilitate post-disaster reconstruction planning and evaluation.

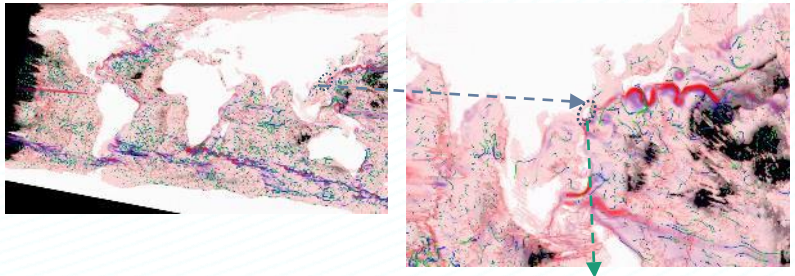


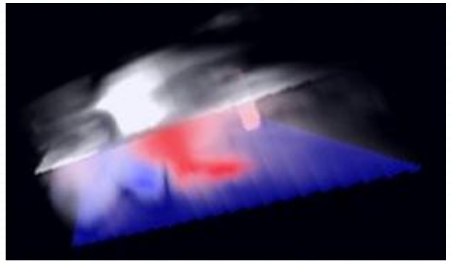
Interior Departments DTM and aerial photo

TASA Formosa-2 satellite images

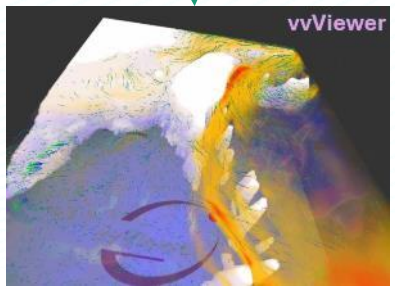
Global Ocean and Atmospheric Simulation

Data from Sinica, NTU, NAMR



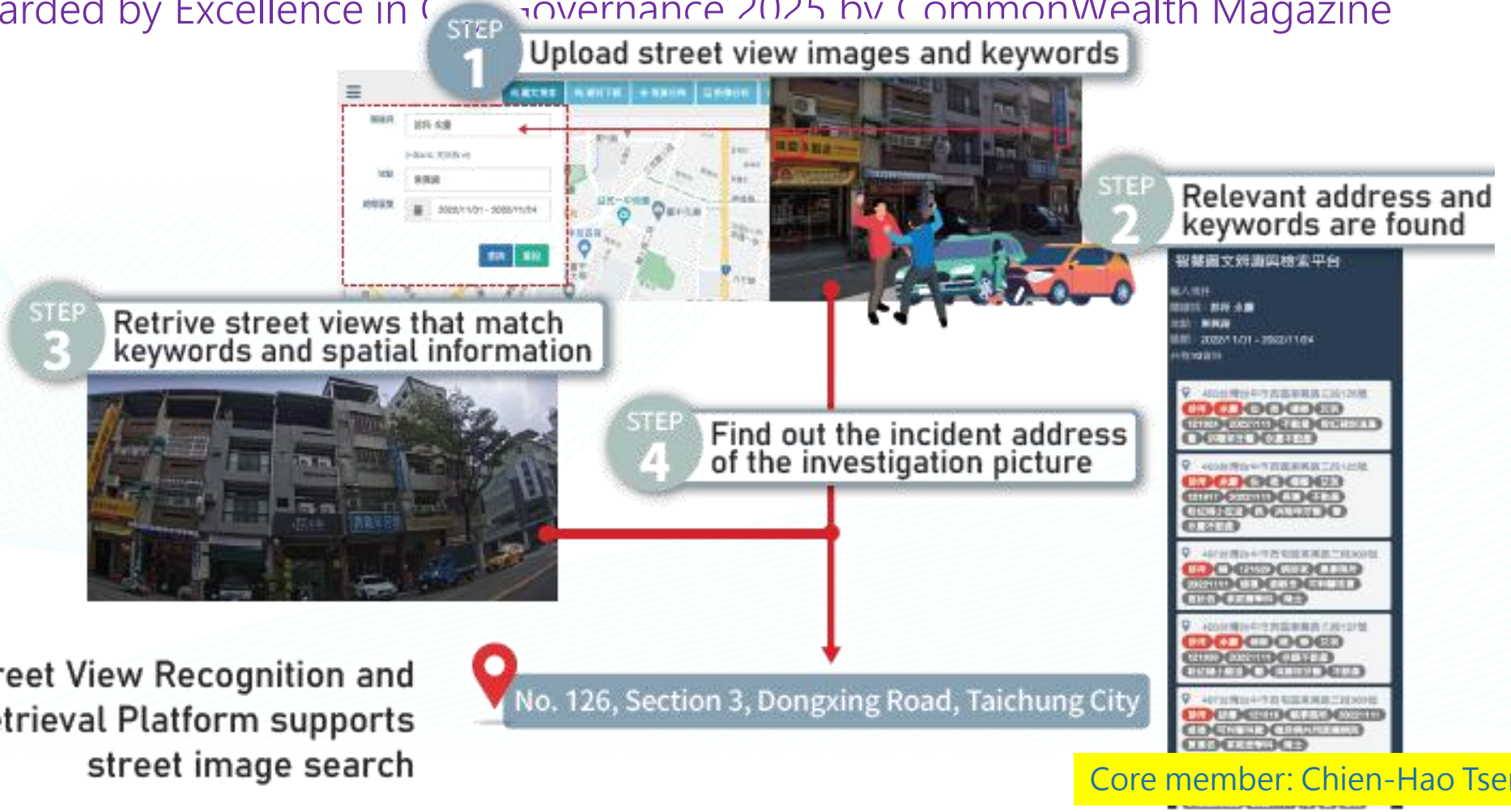


Simulated El Niño ocean-atmosphere anomaly field data (*TaiESM1, WCRP*)



Street View Recognition and Retrieval AI Platform

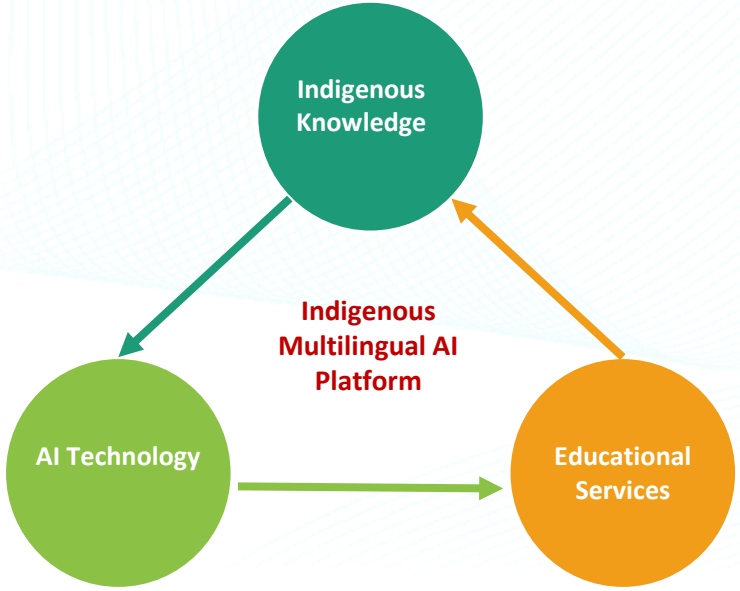
- Search addresses by image; Application of intelligence analysis and **AI Agents** in police investigation
- Enhanced with **LLM-based generation** for comprehension, analysis, and intelligent response
- Taichung awarded by Excellence in City Governance 2025 by CommonWealth Magazine

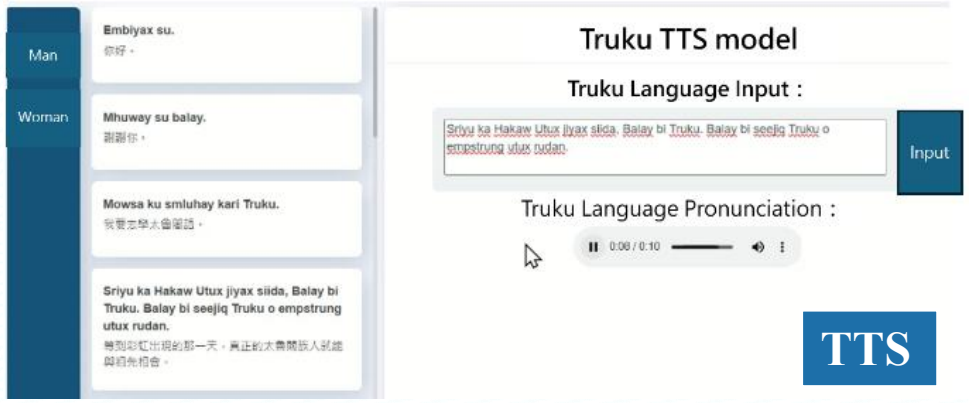


Core member: Chien-Hao Tseng 曾建澔

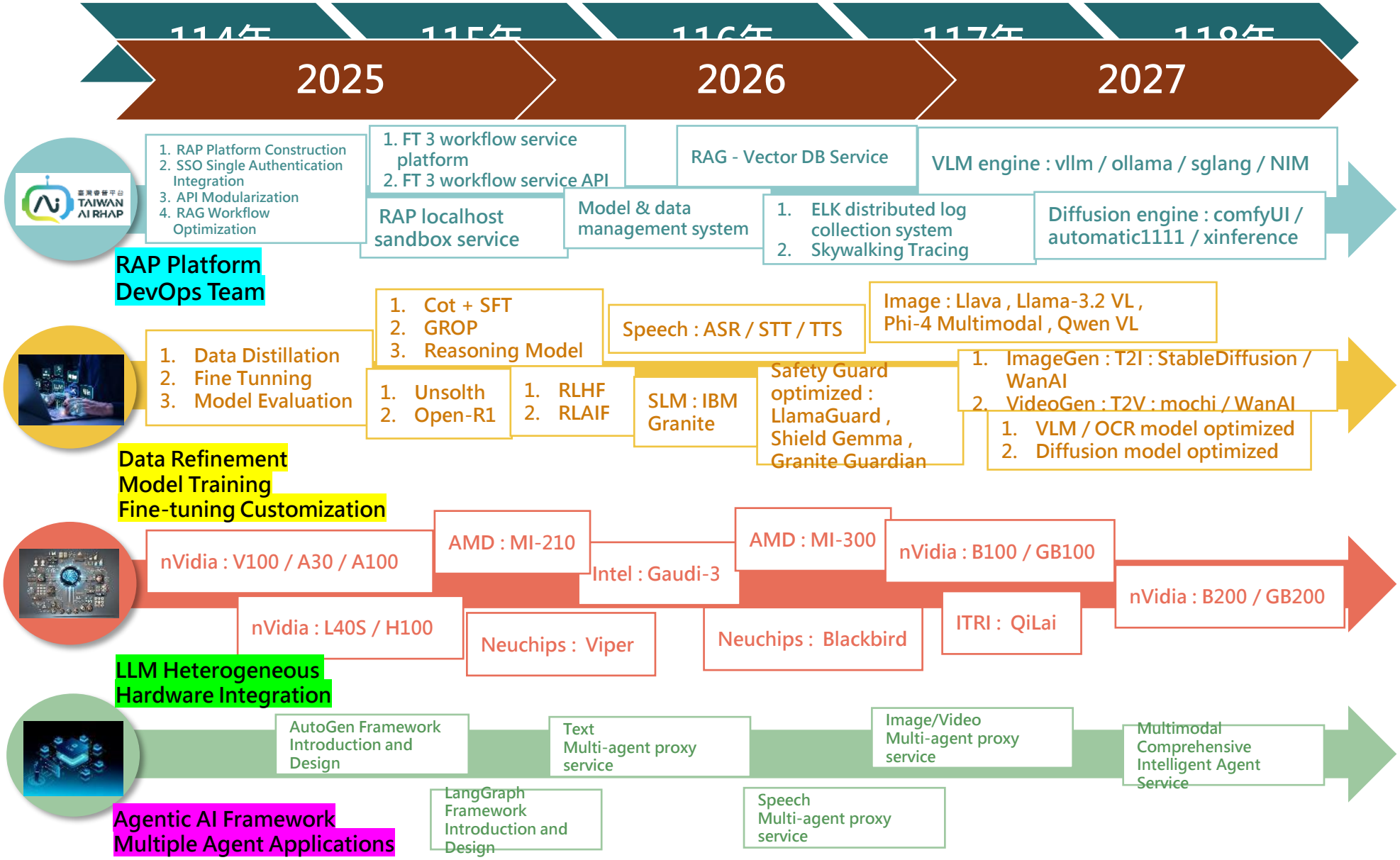
Multilingual Indigenous Language AI/LLM Platform

- Taiwan is home to 16 Indigenous tribes with 42 languages, most endangered
- AI Application services for low-resource languages, grounded in Taiwan's sovereign AI
  - Data Sovereignty – Build indigenous language corpora (Truku, Cou, and Puyuma) in Taiwan and the world
  - Model Sovereignty – Develop low-resource Indigenous language AI/LLM models (ASR, TTS, Translation, Chatbot)
  - Computing Sovereignty – Provide high-performance inference APIs for Indigenous language AI/LLM models





TAIWAN AI RAP - Four Development Tracks



TAIWAN AI RAP - Features & Core Vision

GPT-style Frontend & Customized Workflow Design

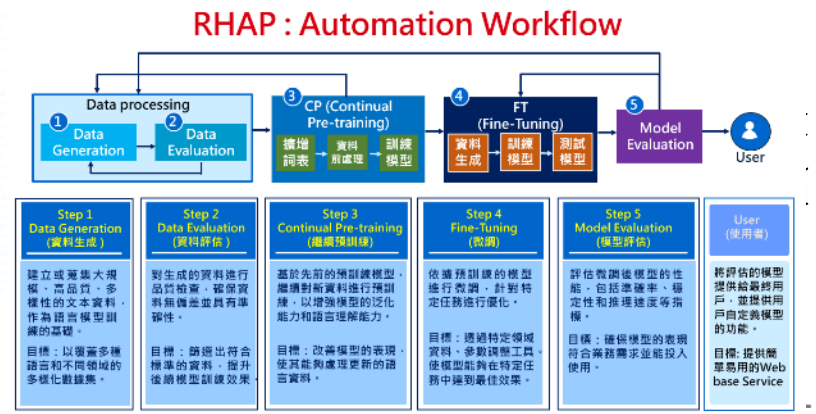
Integrated AI tools and workflow for a low-threshold, flexible development environment — even those without technical backgrounds can use it to develop, deploy, and design interfaces quickly.

Various Open-Source Model API Services

Built-in open-source models, including TAIDE, Llama, Phi, and Mistral series, enabling enterprises to quickly develop value-added services to meet diverse industry AI needs.

Model Fine-Tuning & Evaluation

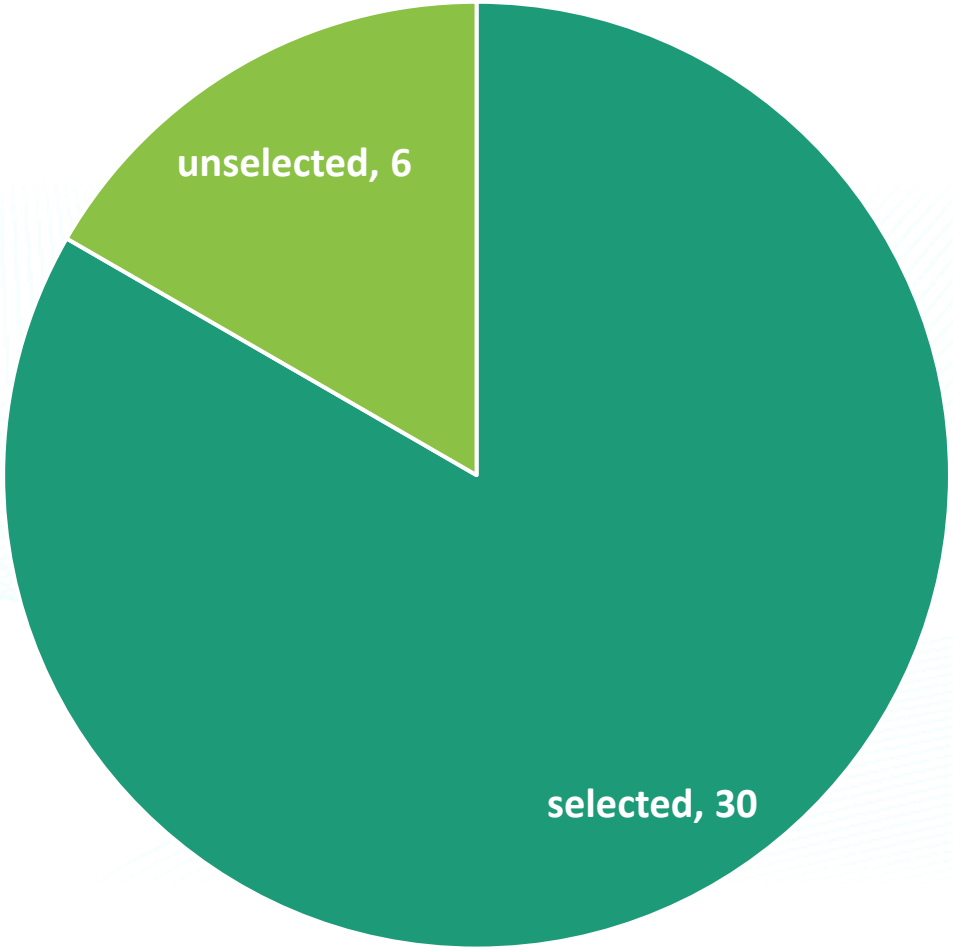
Simplifies model fine-tuning and data processing pipeline, improving model development efficiency.



1st and 2nd Phase Pilot Run : Customer Selection Overview

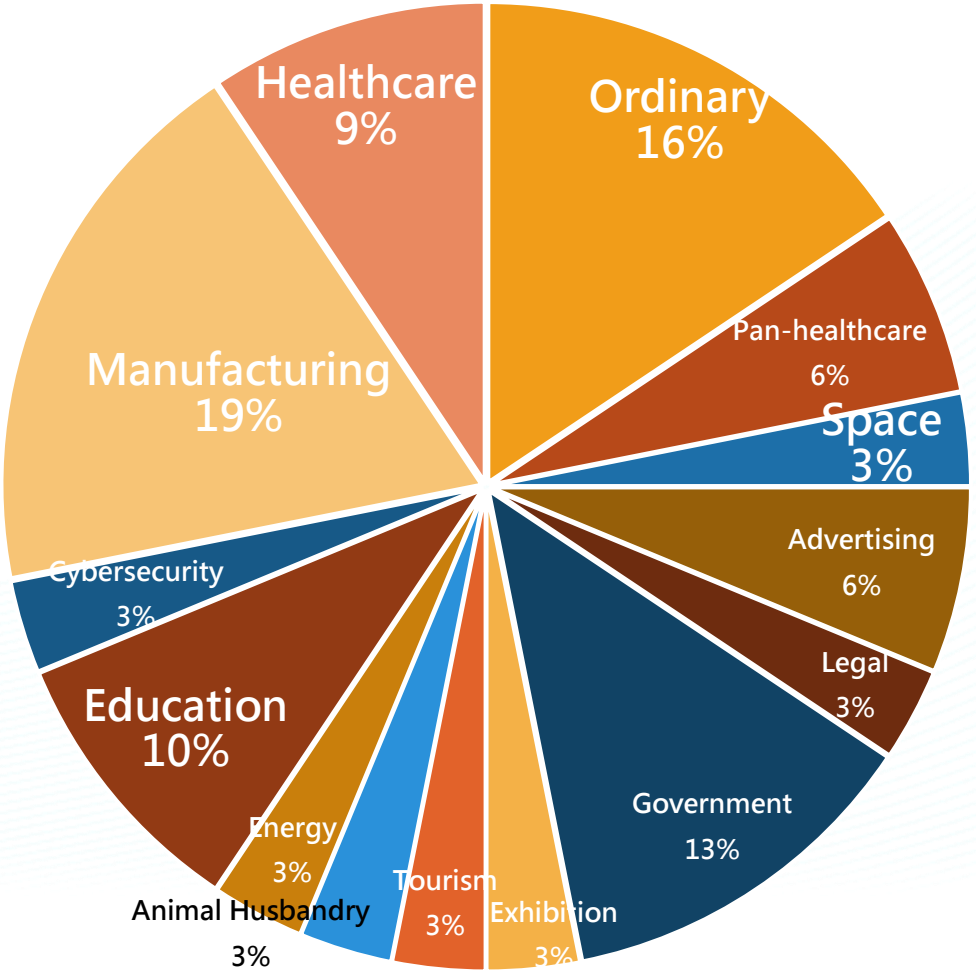
pi run user selection overview

36 applicants, 30 selected; the other 6 referred to the Semiconductor pi run and G-TAIDE cooperation



Pi run user application development fields

30 selected companies across 13 application development fields



Cyber Security

Cyber Defense Exercise Platform

- Cyber Defense Exercise Platform (CDX) is to provide an environment for exercise of information security courses offered in coordination with the government's promotion of information security talent cultivation.
- The platform can be used for long periods of time in coordination with school courses, including the simulation of a real company's network environment with randomly selected vulnerabilities in cyber defense contests, which enhance the hacker defense skills of different sectors.

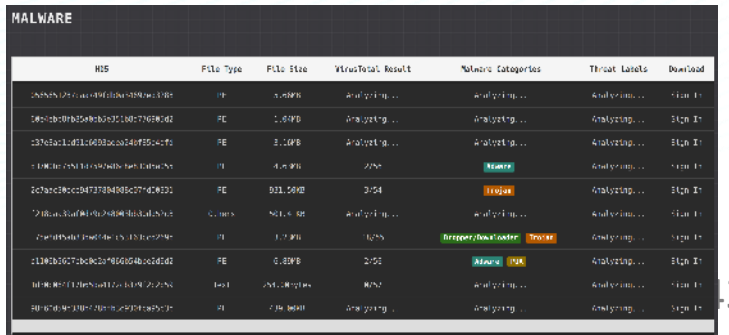
CDX
Cyber Defense eXercise

CIGICIC
網路守護者挑戰賽
CYBER GUARDIAN GRAND CHALLENGE

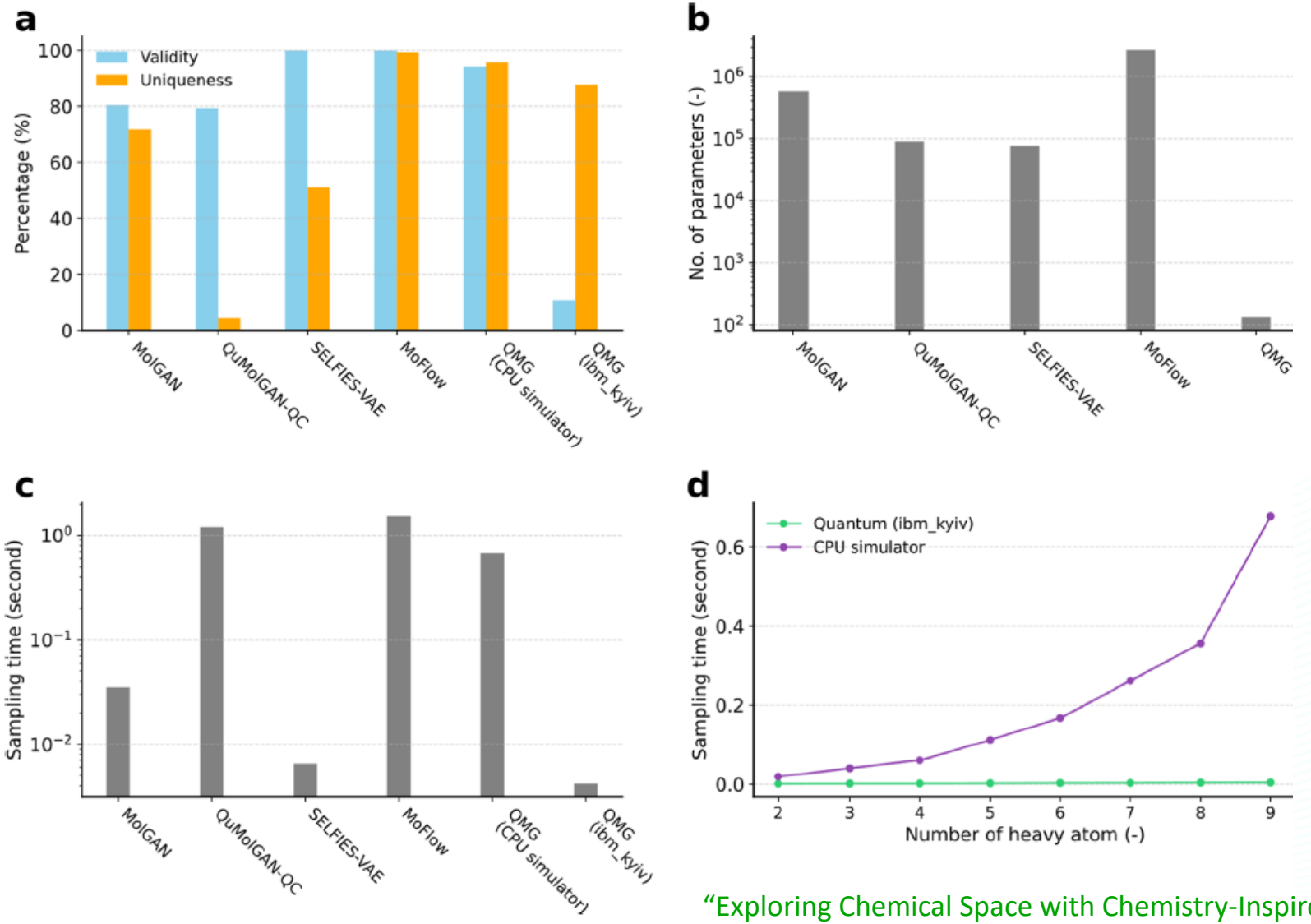
Malware Knowledge Base

- Malware Knowledge Base is a cybersecurity open dataset maintained by the National Center for High-Performance Computing (NCHC). It collects malware samples and analysis reports, serving as a vital resource for malware research.
- To date, the Malware Knowledge Base has accumulated over 33 million distinct malware samples and 13.11 million analysis reports. It also offers data annotation and conditional search capabilities, enabling researchers to efficiently locate the materials they need for their studies.

Malware Knowledge Base



Quantum Molecular Generation (cont.)



"Exploring Chemical Space with Chemistry-Inspired Dynamic Quantum Circuits in the NISQ Era", J Chemical Theory and Comp (2025)

QC: rethink of computing, rebuild development framework

Applications

Programming environment, SDK, Single-source hybrid programming

Domain specific algorithm: PDE solvers, Mesh/particle-based simulation, …

Algorithm: Graph, Sorting, FFT, Monte Carlo, …

Efficient algorithm on Quantum device?

Q algorithm:
- QFT, Quantum sorting, linear solver, …

Classical circult & universal gates: NAND / NOR

Build complex task from gates

Q circuit & universal gates:
- Single qubit gate + two-qubit gate (CNOT)

Classical information based on bit (0-or-1)
- Foundation of today's computing, storage, networking.

Quantum information based on qubit (0-and-1)
- Superposition: (a|0…> + b|1…>)
- Entanglement: (a|00..>+b|11..>)

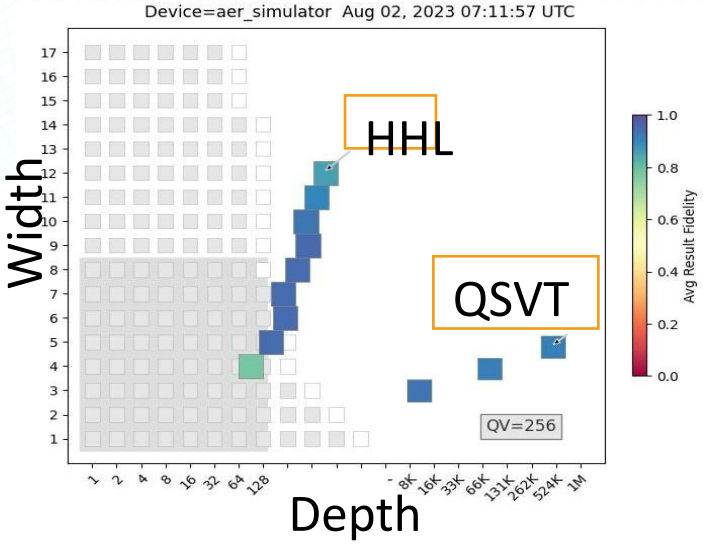
Need quantum RAM, quantum network, and tech that can utilize quantum properties.

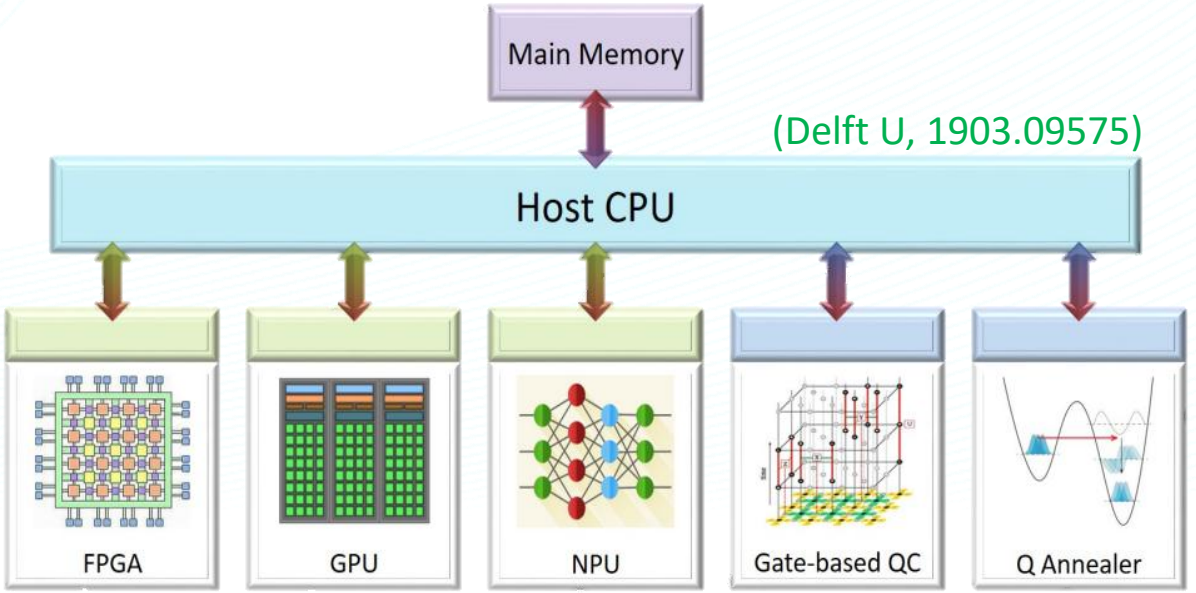
How to represent/encode classical data ?

Computability, Complexity: (non-) deterministic Turning machine, or others

量子電路模擬 與 量子計算應用研究

- 量子計算唯一嶄新的計算模式，重新思考計算邏輯與工作流程。從計算架構角度來看，量子計算可視為異質計算架構的延伸 (如下右圖)。無論從古典及量子計算，都具備挑戰與前瞻性。
- 國網中心目前參與量子國家隊中清大團隊之量子古典計算架構與量子電路模擬研究。
- 主要研究包含：
  - 基本量子電路演算法 Benchmark, 研究 與模擬。(如下左圖比較兩線性系統求解演算法之量子電路深度及寬度的 scaling)
  - CPU/GPU 高速計算之大型量子電路模擬環境建置與 Benchmark：Forerunner 全機量子態 (state vector) 或張量網路模擬
  - 量子優化與量子機器學習，如與 NVIDIA 共同發表大型 QSVM 在GPU環境下的評測 (2405.02630)。





(Delft U, 1903.09575)

Considerations of on-premise quantum computer

On-premise deployment under evaluation for the accelerator model of QC.

- From operation side, technological and supporting considerations matter.

Modality	Super-conducting	Trapped Ion	Photonic	Neutral Atom	Silicon Spin
# Qubits	O(100q)	32Q	20 Photons/ 216 Qumode	100Q	12q
T2 Lifetime	Short 15μs-256μs	Long 0.2s-50s	Short 150μs	Long 0.2s-10s	Mixed 1μs-0.5s
2Q Gate Fidelity	High 99%-99.7%	High 98.5%-99.92%	Promising 98%	Promising 97.4%	Promising 90%-98%
Gate Speed	Fast 10ns-196ns	Mixed 1μs-3ms	Very Fast 1ns	Medium 1μs	Fast 0.8ns-80ns

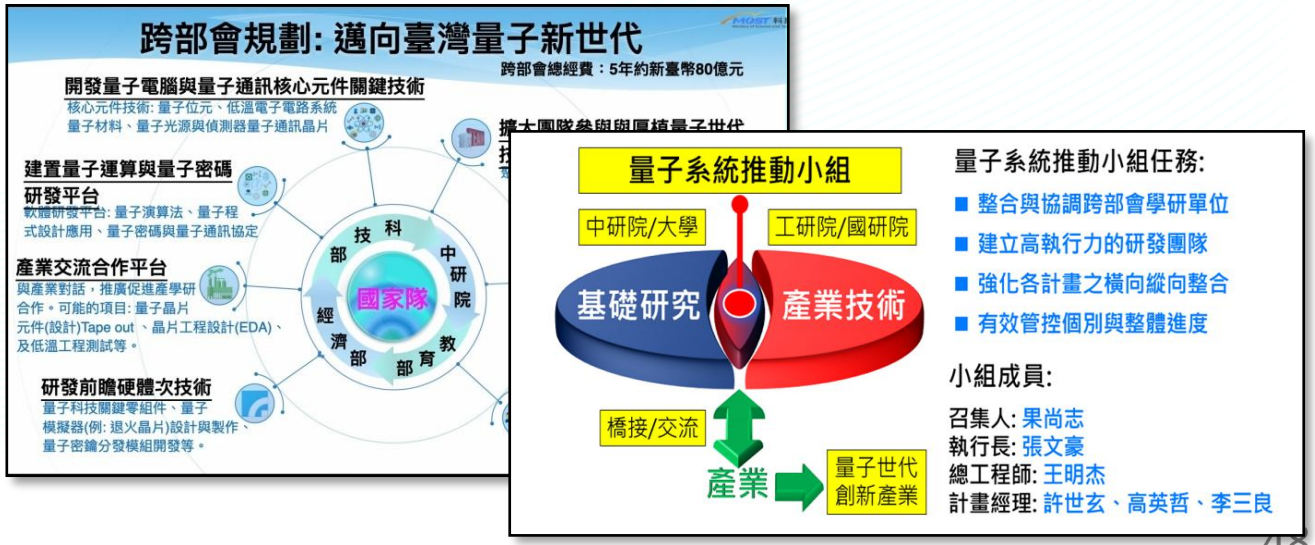
https://quantumtech.blog/2022/10/20/quantum-computing-modalities-a-qubit-primer-revisited/

Advantages:

1. **Latency:** of hybrid Q algorithms.
2. **Streamlining operations:** from simulators to quantum devices
3. **Device Autonomy:** for ore customization and tuning possibility
4. **Security & Privacy.**

Taiwan Quantum Program (2021-2025)

- Hardware for universal QC
  - Silicon-based Q dot (NTU Phy)
  - DC/RF spice model for CryoCMOS (NTU GIEE)
  - Superconducting parametric amplifier (NTHU Phy)
  - Material for superconducting Q circuit (NTHU Phy)
  - Germanium qubits & CMOS IC (NYMCTU IE)
  - Cesium array neutral atom QC (AS IAMS)
  - Superconducting QC (AS IoP)
- Silicon photonic QC and comm
  - QKD fiber comm tech (NTU GIPO)
  - QRNG (NTHU IPT)
  - Metropolis comm network (NTHU Phy)
  - Error corrected photonic chip (NCU DOP)
- Software & Applications
  - Noise characterization in Q simulation (NTU Chem)
  - **Q virtual machine & Q-C architecture (NTHU Phy)**
  - Error correction in NISQ (NYMCTU EE)
  - Q program, (post-)Q crypto, and tomography theory (AS IIS)
  - Industrial optimization & Finance (CYCU Phy)
  - Q compiling system (NTU GIEE)



QC application -- Examples

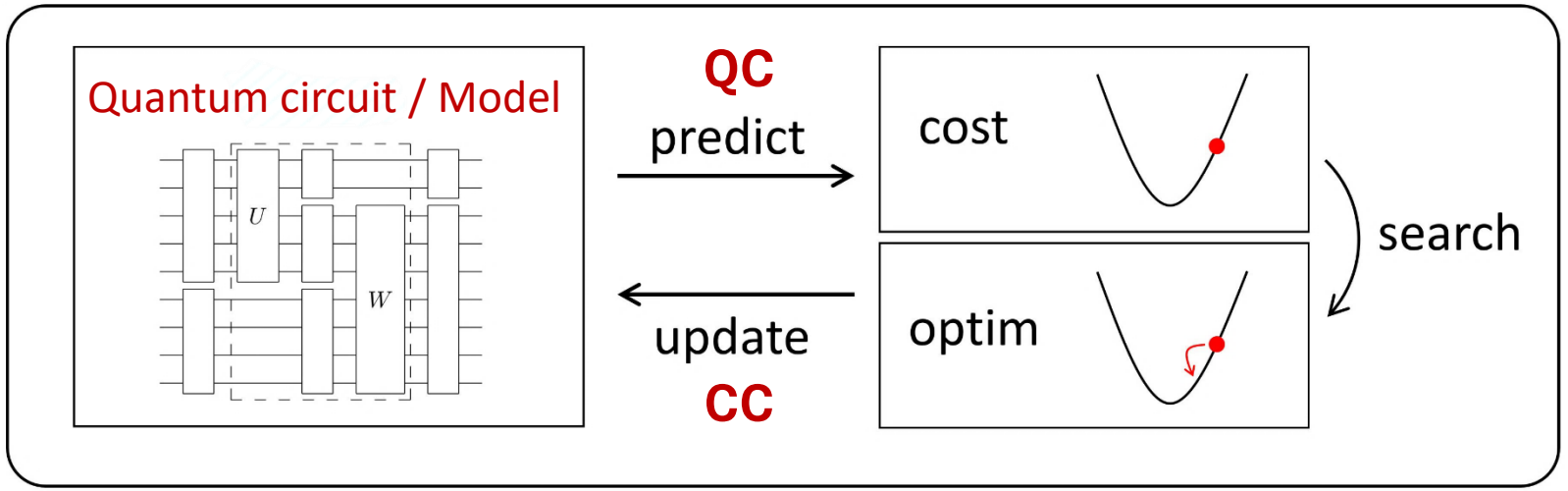
- Finance
  - Portillo opt (Barclays)
- Energy and materials
  - Safer, lighter, and cost-effective battery materials (Volkswagen/Xanadu)
  - Accelerate oxygen reduction reaction (ORR) for **fuel cell (**BMW/Airbus/**Quantinuum)**
- Chemicals & Pharmaceuticals
  - Better enzyme inhibitors for drug discovery (Kuano)
  - **Chemistry, Logistics and Scheduling** (BASF/Nvidia)
  - Electronic structure simulation (Dow/IonQ)
- Travel & Logistics:
  - Coordinate LNG carriers and requirement (ExxonMobil/IBM)
  - Persistent supply chain; Last mile delivery (IBM)
  - Disruption management
- Advanced industries …

Underlying problems:

- Combinatorial optimization
- Quantum simulation
- Solving linear equations

Hybrid quantum-classical algorithms

- Almost every Q algorithms are “hybrid” Callison and Chancellor, 2207.06850
  - Classical intervention in Problem mapping, State preparation, Post-selection, Error correct/mitigation…
- Variational Quantum Algorithms (VQA)
  - Offload cost function evaluation to QC
  - N-qubit operation ($2^N \times 2^N$ matrix) is modeled by far fewer parameters with certain state/circuit ansatz
  - Training VQA is NP-hard problem Bittel and Kliesch, PRL 2021
  - Example: VQEigensolver, QAOA, QML, …

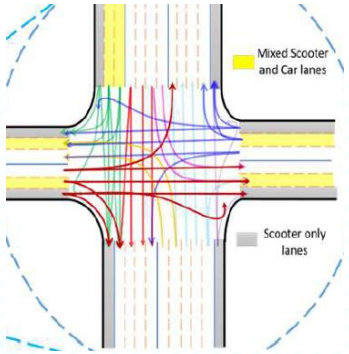


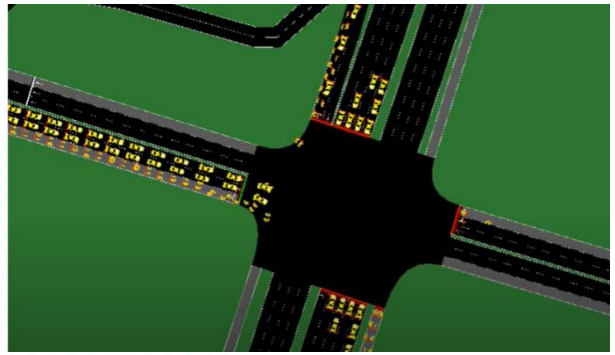
- Q assisted algorithms: QC calculate all needed matrix elements at once avoiding feedback cycle

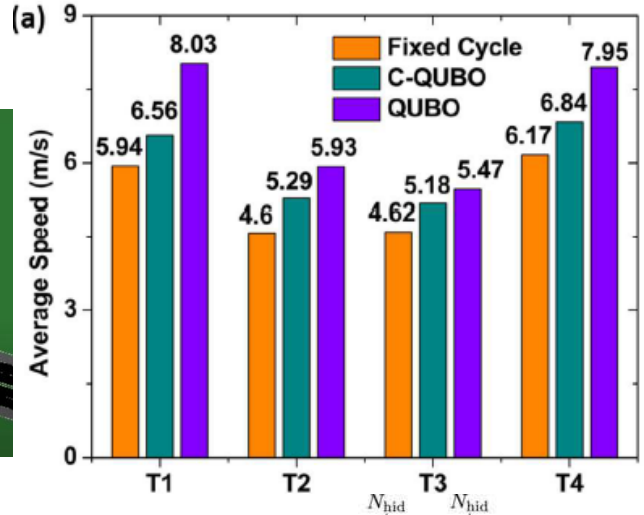
Optimization -- from QUBO to QAOA

Amit+ 2021
NCHC internship

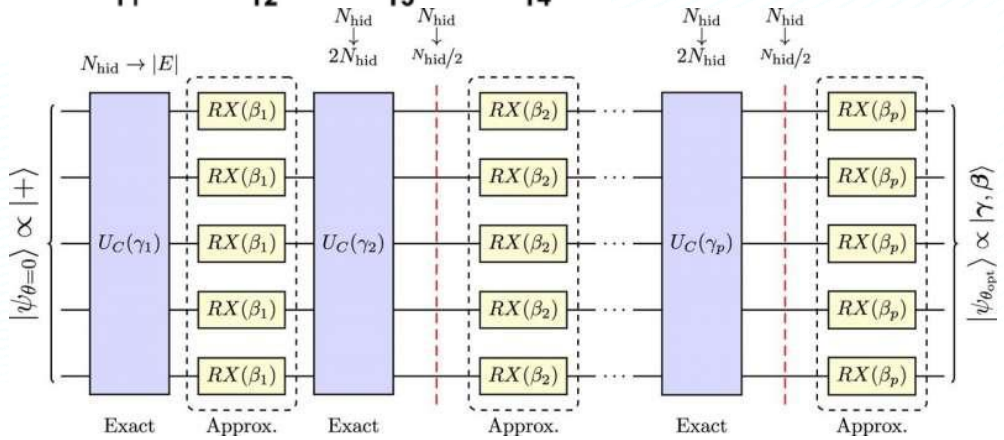
- **Traffic light control** on **SUMO simulator via QUBO**
  - **Quadratic Unconstrained Binary Optimization (QUBO)** → **to** find ground state energy of Ising model
  - Minimize #car in the intersection as cost function
  - Higher avg. velocity for various traffic conditions







- QAOA (Q Approximate Optimization Algorithm)
  - A VQA with many ansatz variants, see 2306.09198
  - Barren plateaus in training large circuits
  - Intel report max-cut requires O(100) qubits for Q speed-up

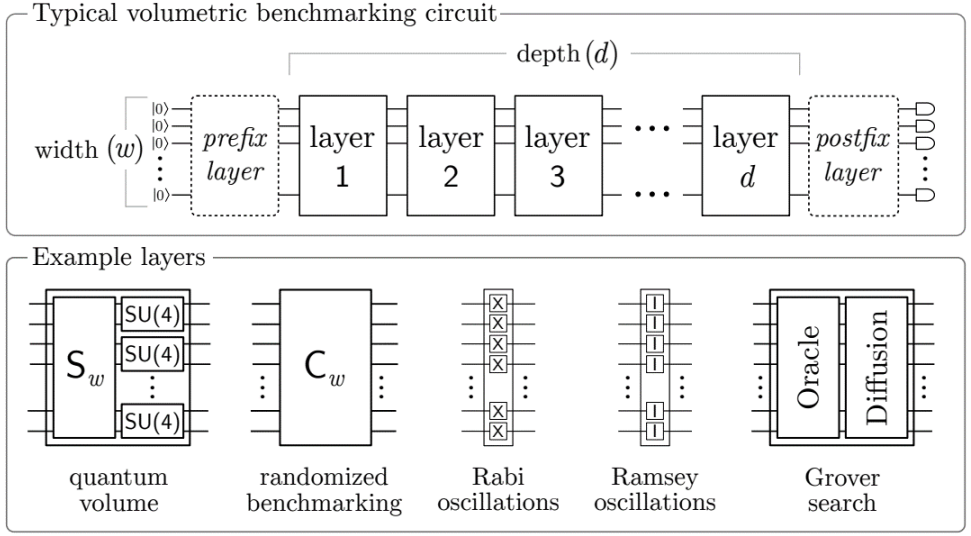


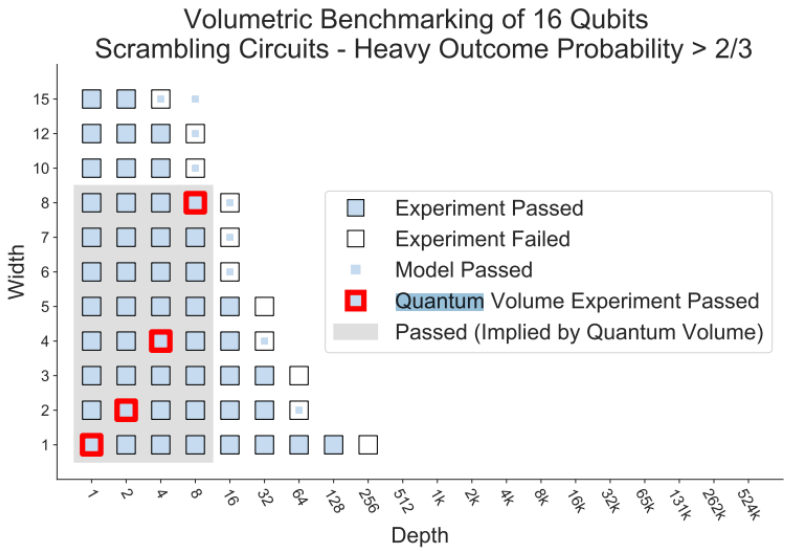
Benchmark & Characterization

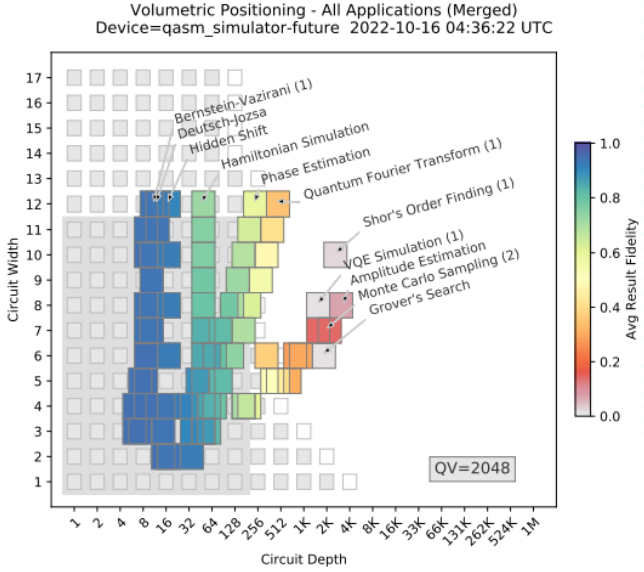
- Single metric may NOT capture whole picture:
  - Gate fidelity from Randomized benchmark (RB)
  - Quantum volume (QV), Cross-entropy benchmark (XEB)
- General gate-set tomography is parameter estimation problem.

1904.05546, 2110.03137

- Application-oriented benchmarks (by QED-C) characterize hardware-depended behaviors
  - Cf. Roofline model in HPC
  - Similar with IonQ's Algorithmic qubits (#AQ)





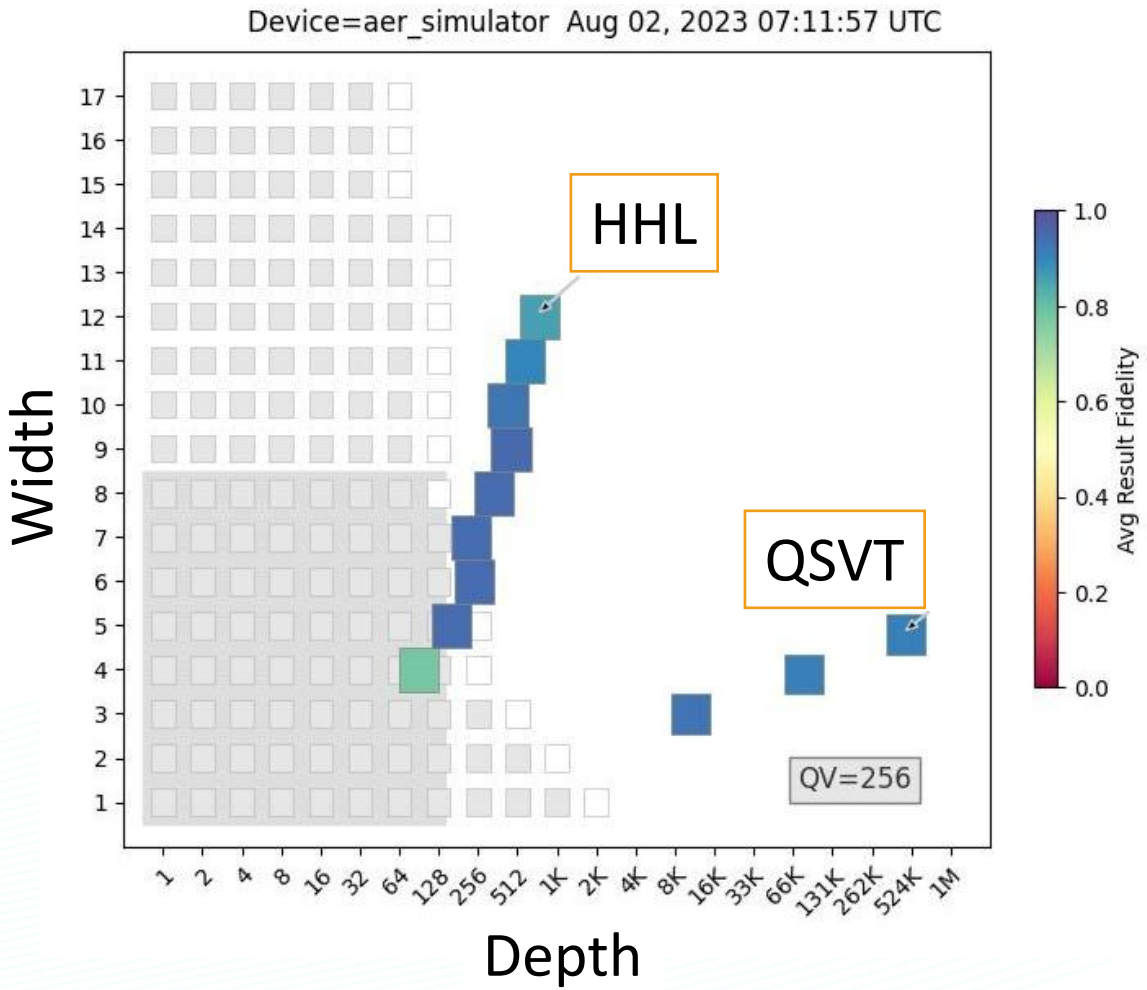


Solving linear equations -- HHL vs QSVT

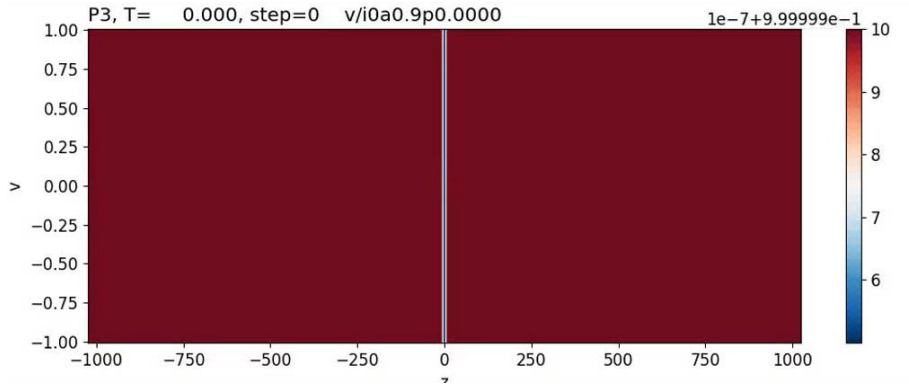
Lin and Ning, 2023
NCHC internship

- Benchmark cases:
  - Solve Ax=b problems for A = 2x2, 4x4, 8x8
  - Ideal simulator w/ 4 primitive gates

- Vanilla HHL:
  - Circuit input: b
  - **A**-op is in Q phase estimation: More qubits needed
  - Post-selection of ancilla qubit
- Q singular value transform (QSVT):
  - General Q signal processing framework (2019)
  - **A** was Hermitian-block-encoded into larger matrix (N+1)
  - Iteratively approximate the inverse.
  - Less qubits but far deeper circuit

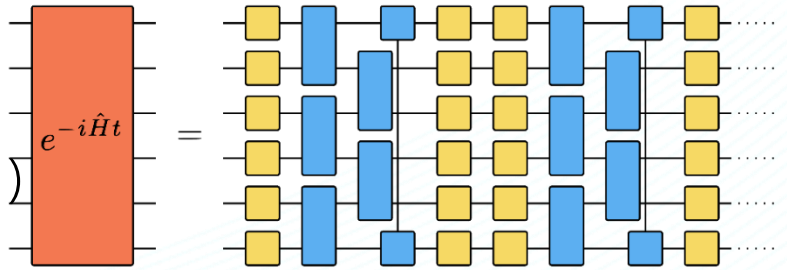


Toward neutrino many body simulation

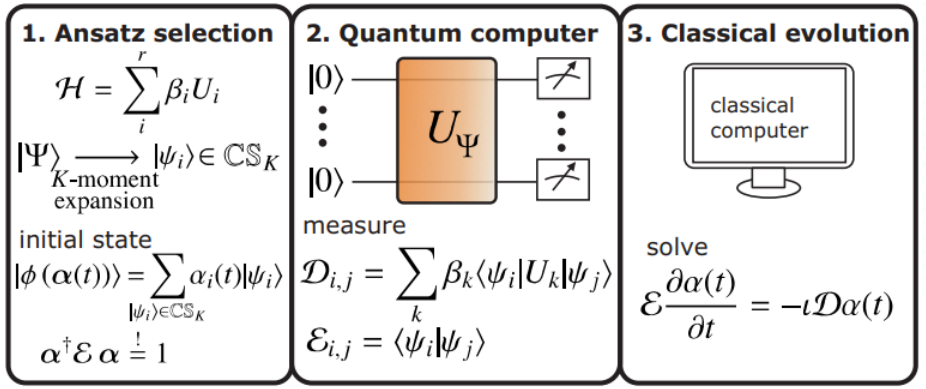


- Neutrinos are complicated many-body problem astrophysically
  - Small perturbation can trigger flavor instability
  - Classical mean-field simulation may fail to capture intrinsic Q effect.
  - There is many-body effects beyond mean field behavior (2203.02783)
- Trotter Q simulation of small system demonstrates the real-time evolution of entanglement entropy
  - Many SWAP gates for all-all interaction
  - Trotter decomposition results deep circuit

$$i\frac{\partial \psi(t)}{\partial t} = H\psi(t)$$



- Quantum assisted simulator with reduced CNOT gates (2308.09123)
  - Assume H = U1 + U2 + U3 +… unitary operator
  - Ansatz are |0> acted by Us and their powers (K-moment states)



Concluding remarks

- A thrilling time to witness Q information science → Q computing.
- QC promising for more complex problem, but challenges remain.
- Accelerator QC model naturally fit and enrich today's HPC model.
- Q advantage comes from advances of **both** Q / classical computing techniques.
- We currently focus on core algorithms and benchmarks:
  - QAOA for combinatorial optimization
  - Algorithms for solving linear equations
  - Quantum assisted simulation
  - Operate a GPU cluster to support Q program
- Evaluating Q-C integration with real quantum device (cloud/on-premise) is underway.

~ Thank you ~

國家實驗研究院
國家高速網路與計算中心
National Center for High-performance Computing

Scalable Quantum Circuit Simulation on HPC Platform

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Main Works

- Scalable Quantum Support Vector Machine Simulation
- Quantum Circuit for Molecular Generation

Scalable Quantum Support Vector Machine Simulation

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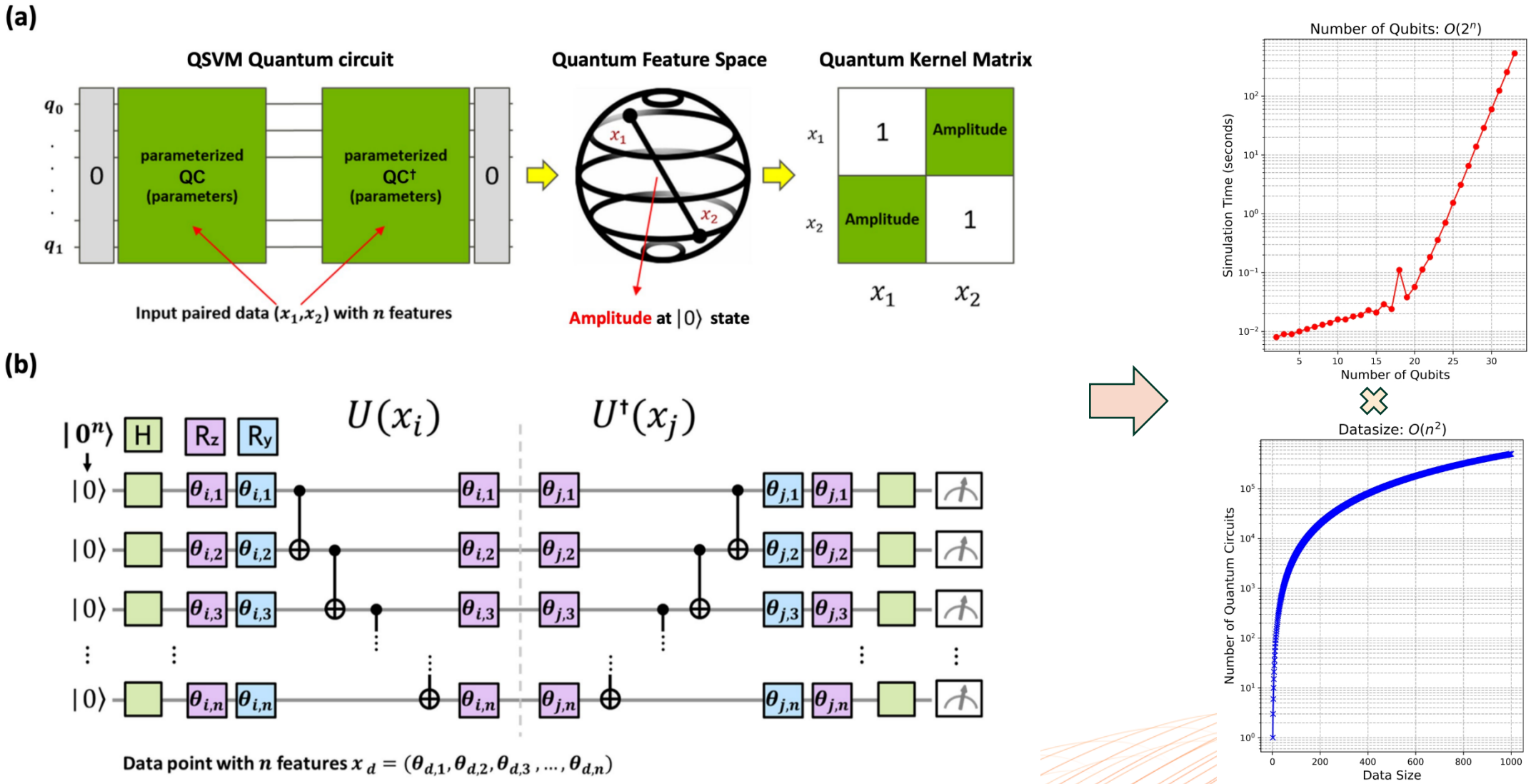
QSVM Workflow and Computational Complexity on HPC Platform

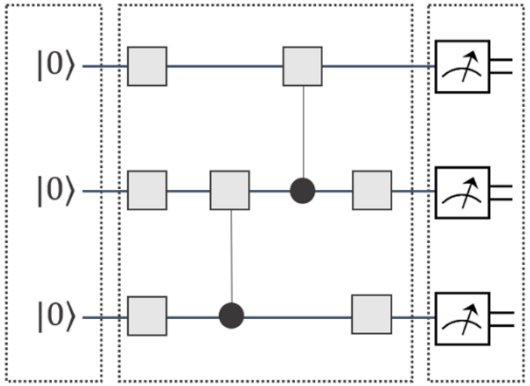


Scalable Quantum Support Vector Machine Simulation

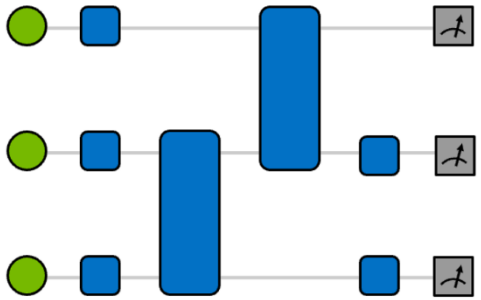
Tensor Network Simulation using cuQuantum

(a)

Quantum circuit

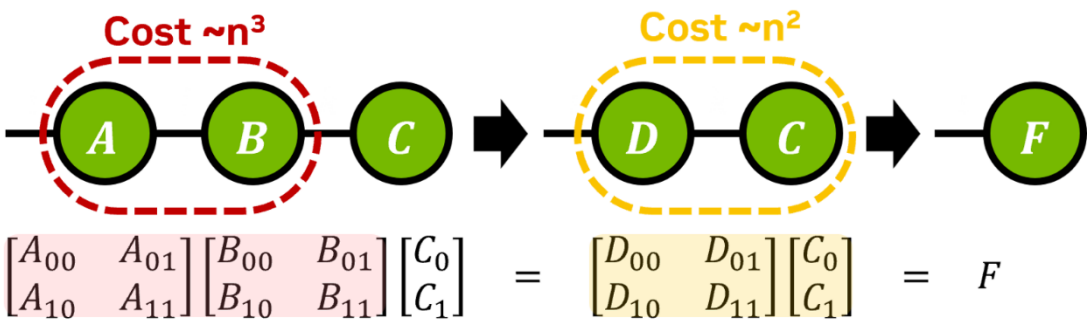


tensor network representation

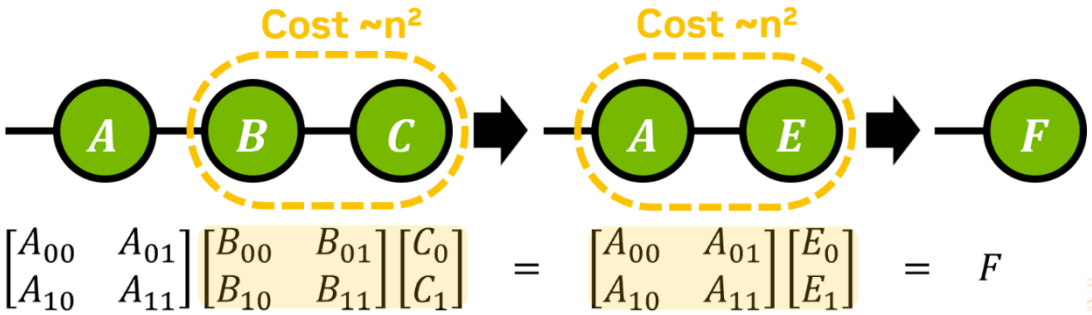


(b)

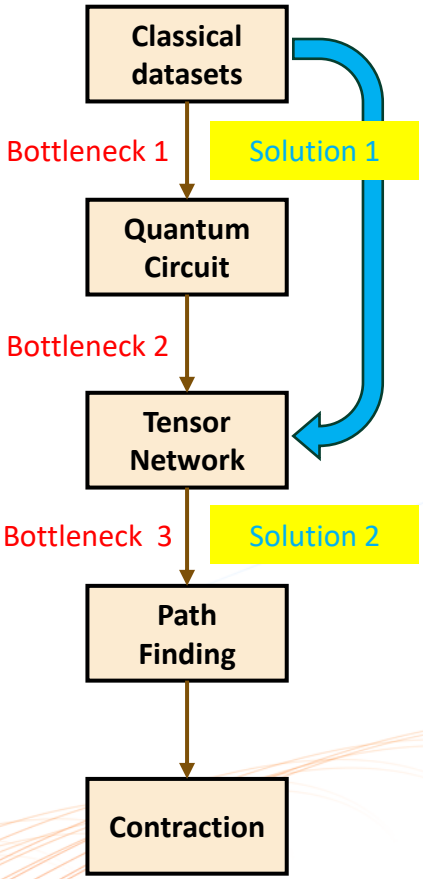
Contraction path 1



Contraction path 2

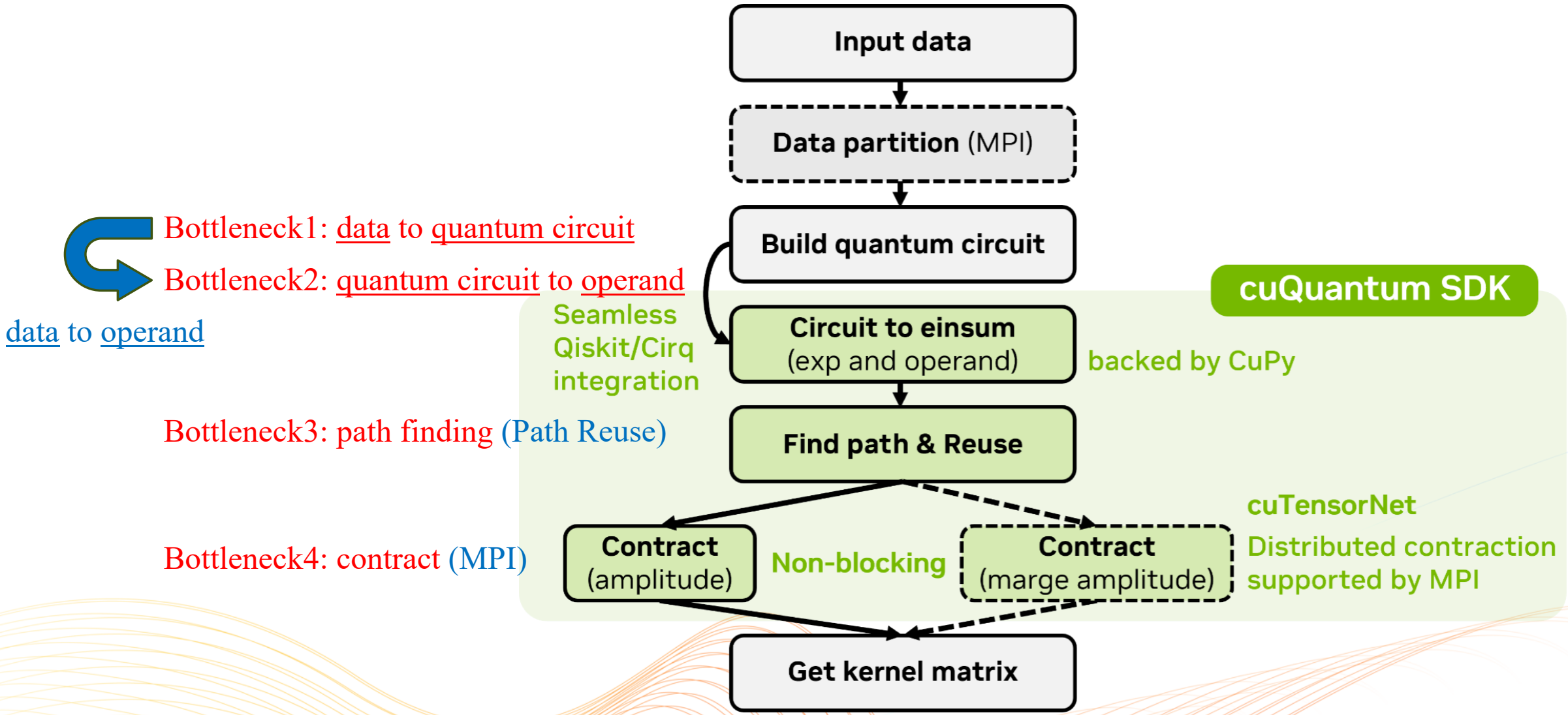


Optimize Workflow



"Validating Large-Scale Quantum Machine Learning: Efficient Simulation of Quantum Support Vector Machines Using Tensor Networks", Machine Learning: Science and Technology **6**, 015047, 2025.

Scalable Quantum Support Vector Machine Simulation



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Scalable Quantum Support Vector Machine Simulation

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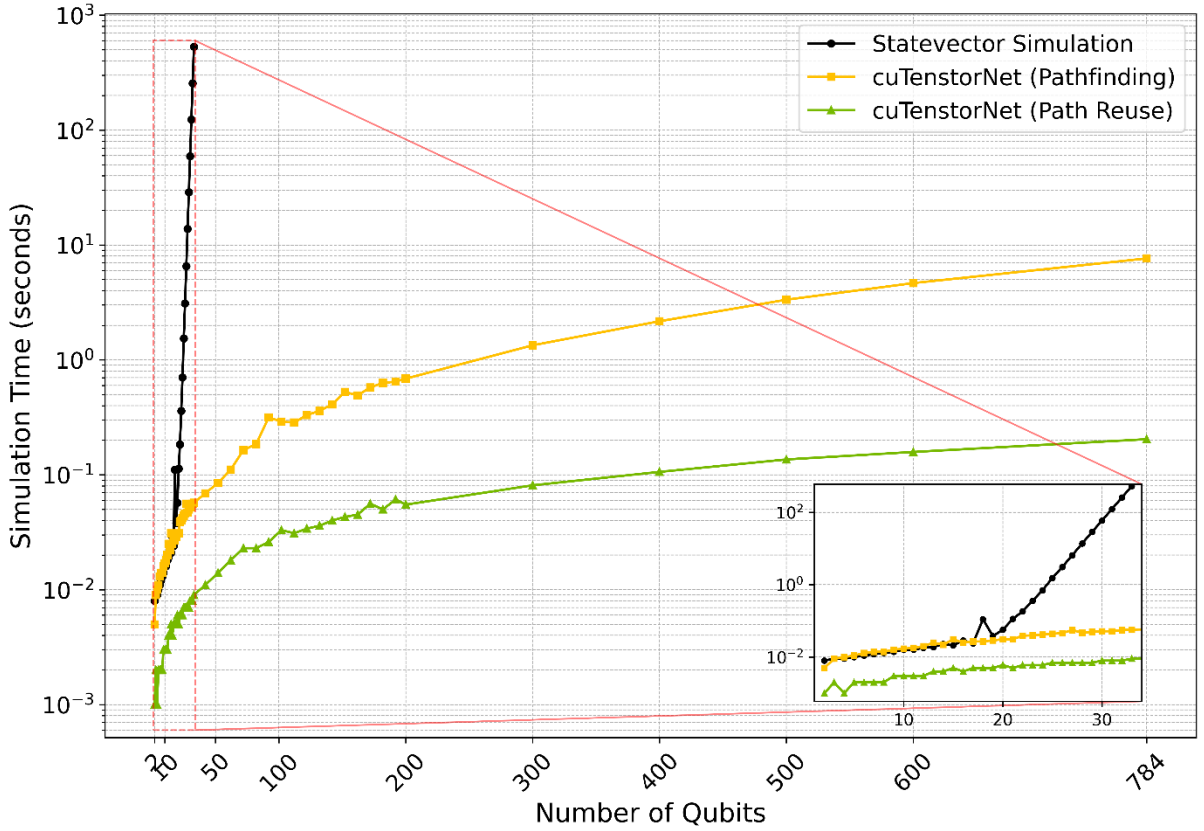
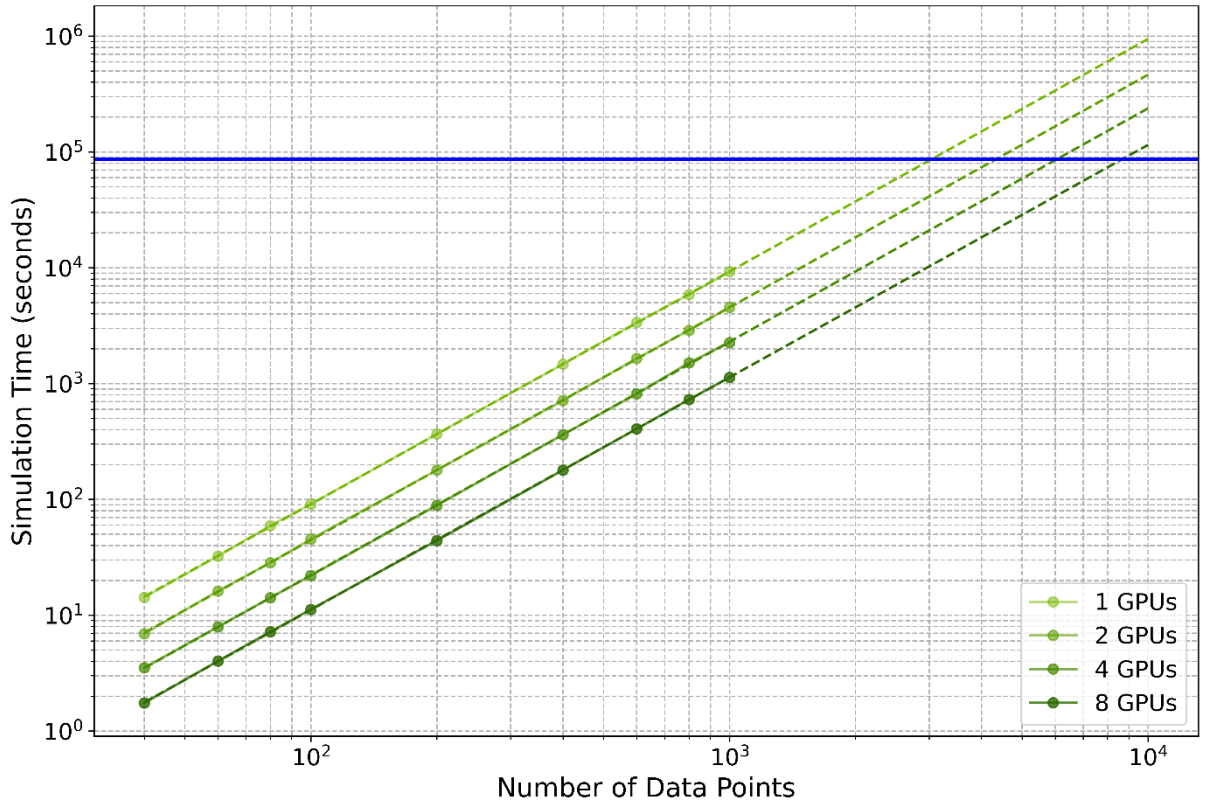
Single-GPU and Multi-GPUs Benchmark





"Validating Large-Scale Quantum Machine Learning: Efficient Simulation of Quantum Support Vector Machines Using Tensor Networks", Machine Learning: Science and Technology **6**, 015047, 2025.

Quantum Circuit for Molecular Generation

No. of heavy atoms	No. of qubits required for **static** circuit	No. of qubits required for **dynamic** circuit	No. of parameters in dynamic circuit	Valid proportion of quantum state (%)
2	6	6	8	45.32
3	12	8	17	10.67
4	20	10	29	1.10
5	30	12	44	0.04
6	42	14	62	-
7	56	16	83	-
8	72	18	107	-
9	90	20	134	-
N	$N(N+1)$	$2(N+1)$	$8+3(N-2)(N+3)/2$	-

"Exploring Chemical Space with Chemistry-Inspired Dynamic Quantum Circuits in the NISQ Era", ACS Journal of Chemical Theory and Computation **21**, 6653, 2025.

Quantum Circuit for Molecular Generation

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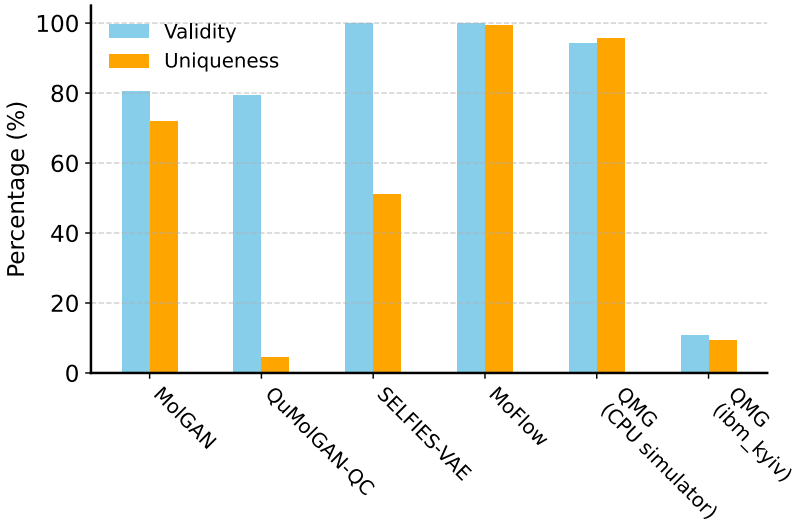
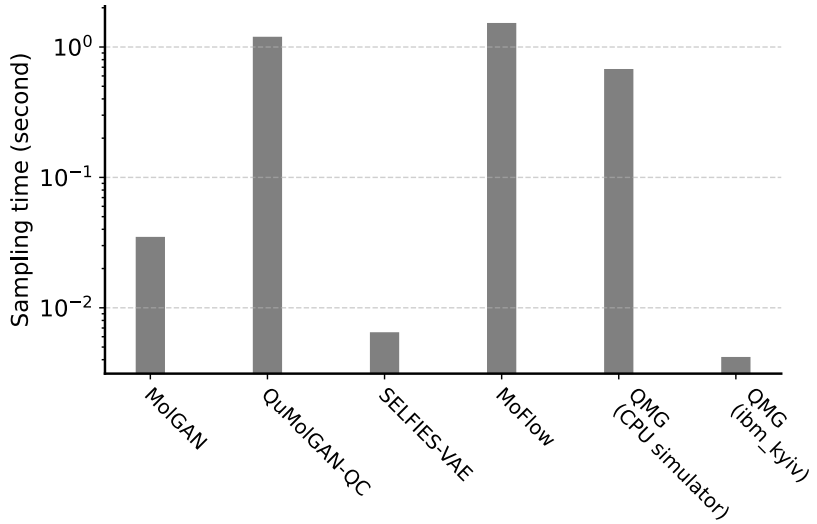
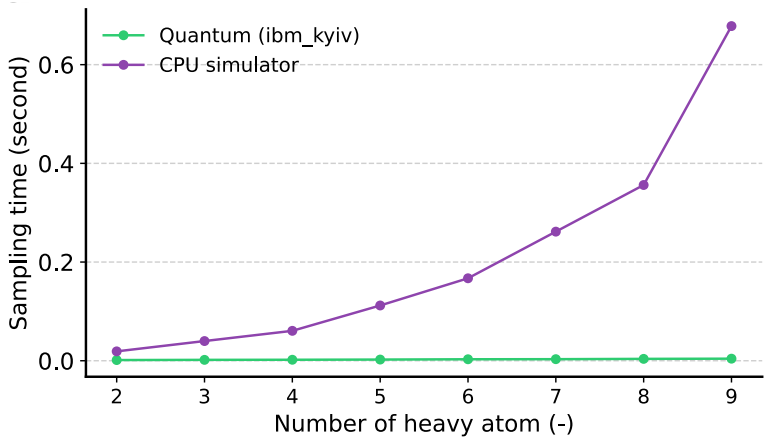
Benchmark Result

Model	Validity (%) (↑)	Uniqueness (%) (↑)	No. of parameters (↓)
MolGAN [1]	80.40	71.89	~576,000
QuMolGAN-QC [2]	79.39	4.49	~90,000
SELFIES-VAE [3]	100	51.08	~77,000
MoFlow [4]	100	99.26	~2,712,000
QMG (Ours)	93.9	94.6	**134**







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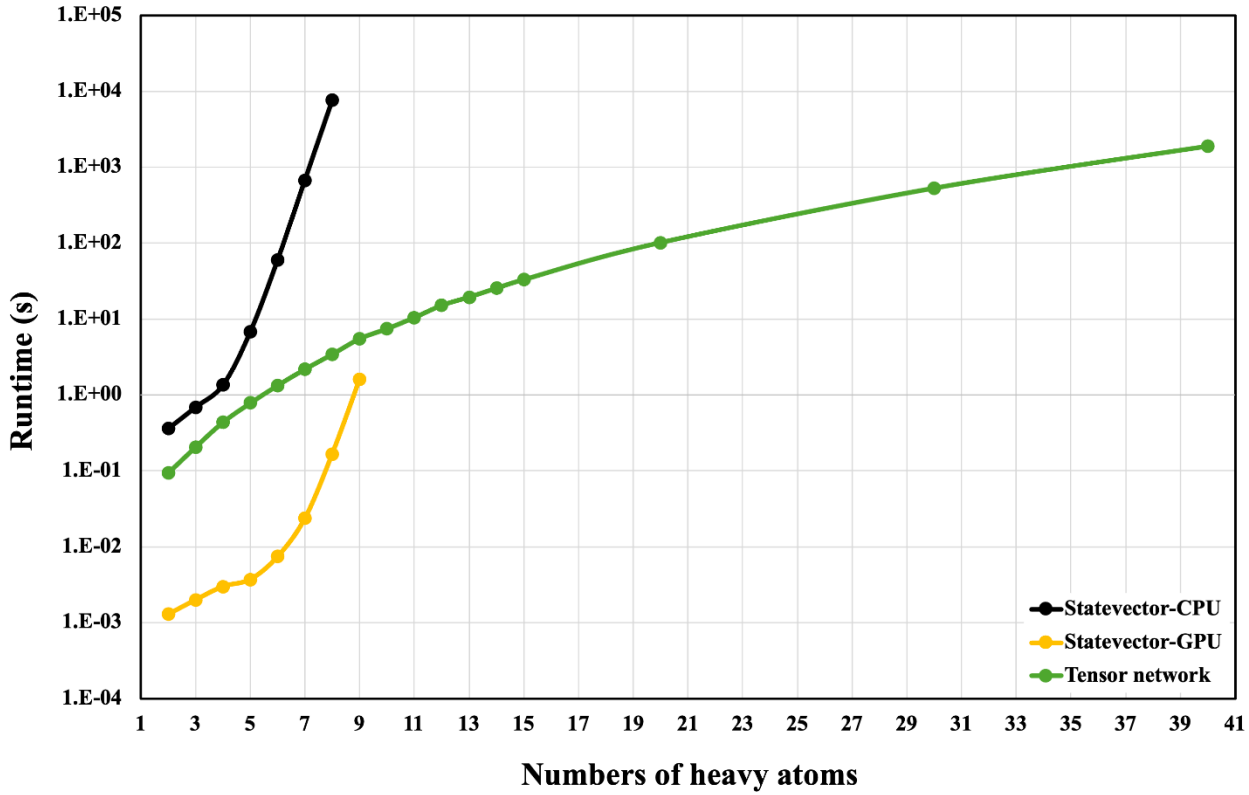
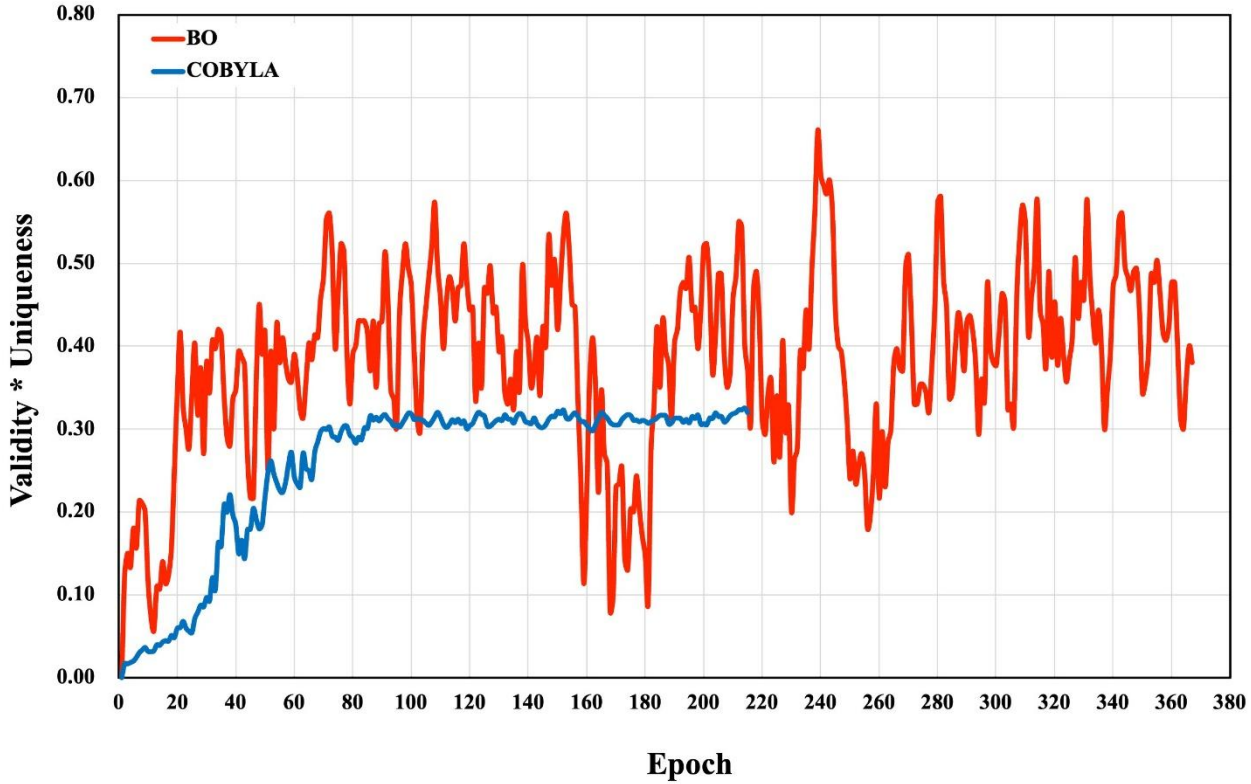
Quantum Circuit for Molecular Generation





Collaboration

1. Large Scale Quantum Circuit Simulation by TN
2. QMG + QRL

Quantum Machine Learning Works

- Quantum Kernel-based Long Short-Term Memory
- Hybrid Quantum Machine Learning Pipeline for High-Dimensional Neuroimaging Data
- Quantum Pointwise Convolution Networks
- Quantum Graph Attention Network
- Quantum Adaptive Excitation Network for Channel Attention

Quantum Kernel-based Long Short-Term Memory

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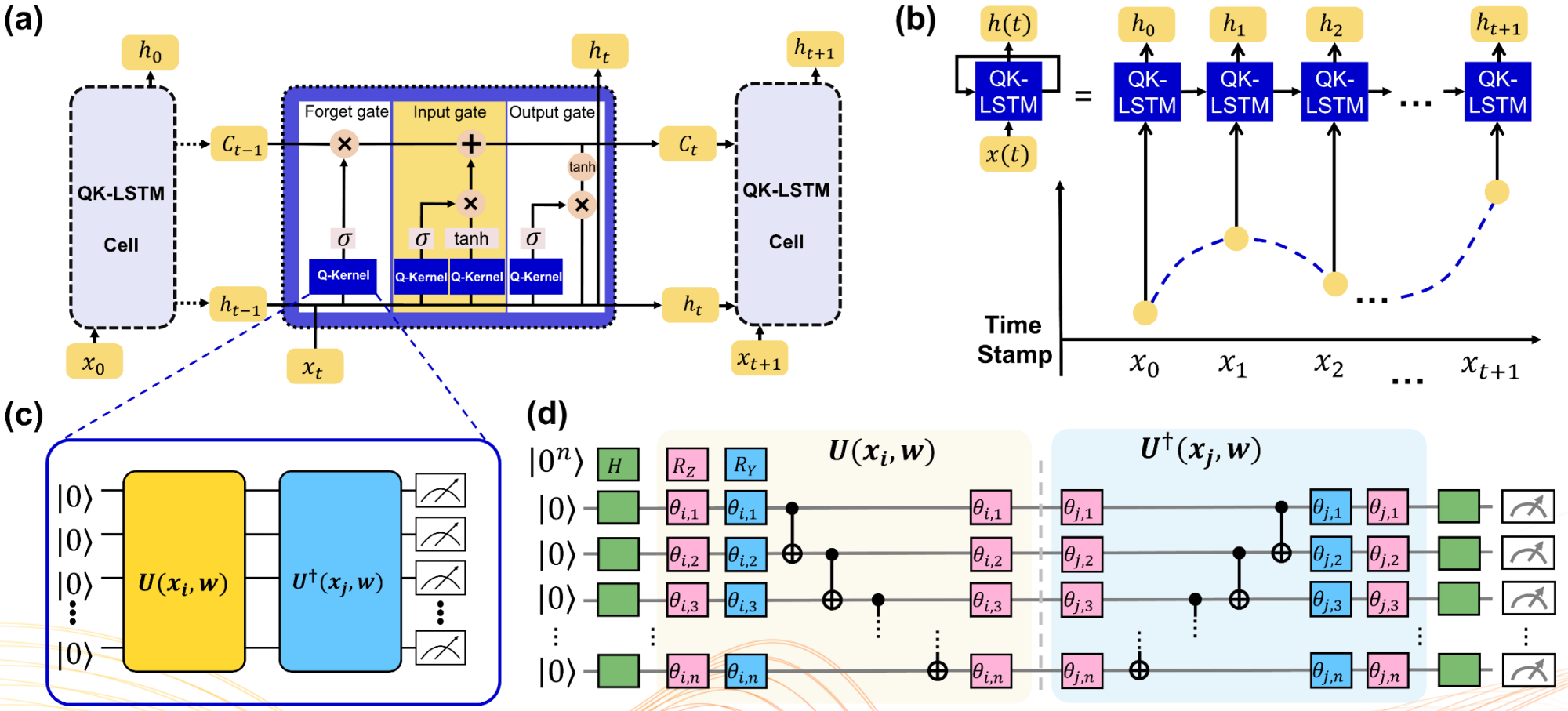
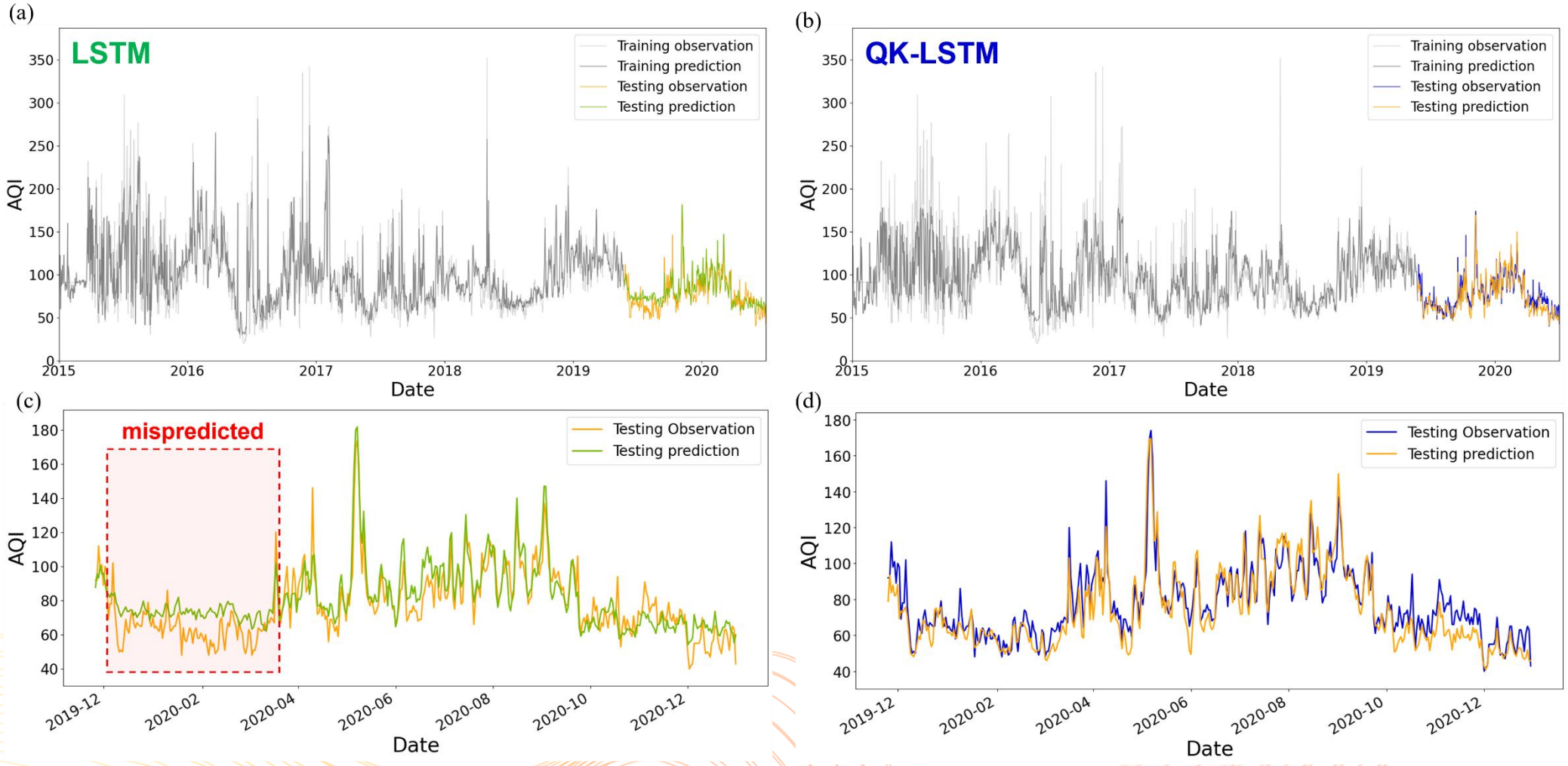
Overview of the QK-LSTM architecture



"Quantum Kernel-Based Long Short-term Memory for Climate Time-Series Forecasting", IEEE QCNC 2025, https://arxiv.org/abs/2412.08851

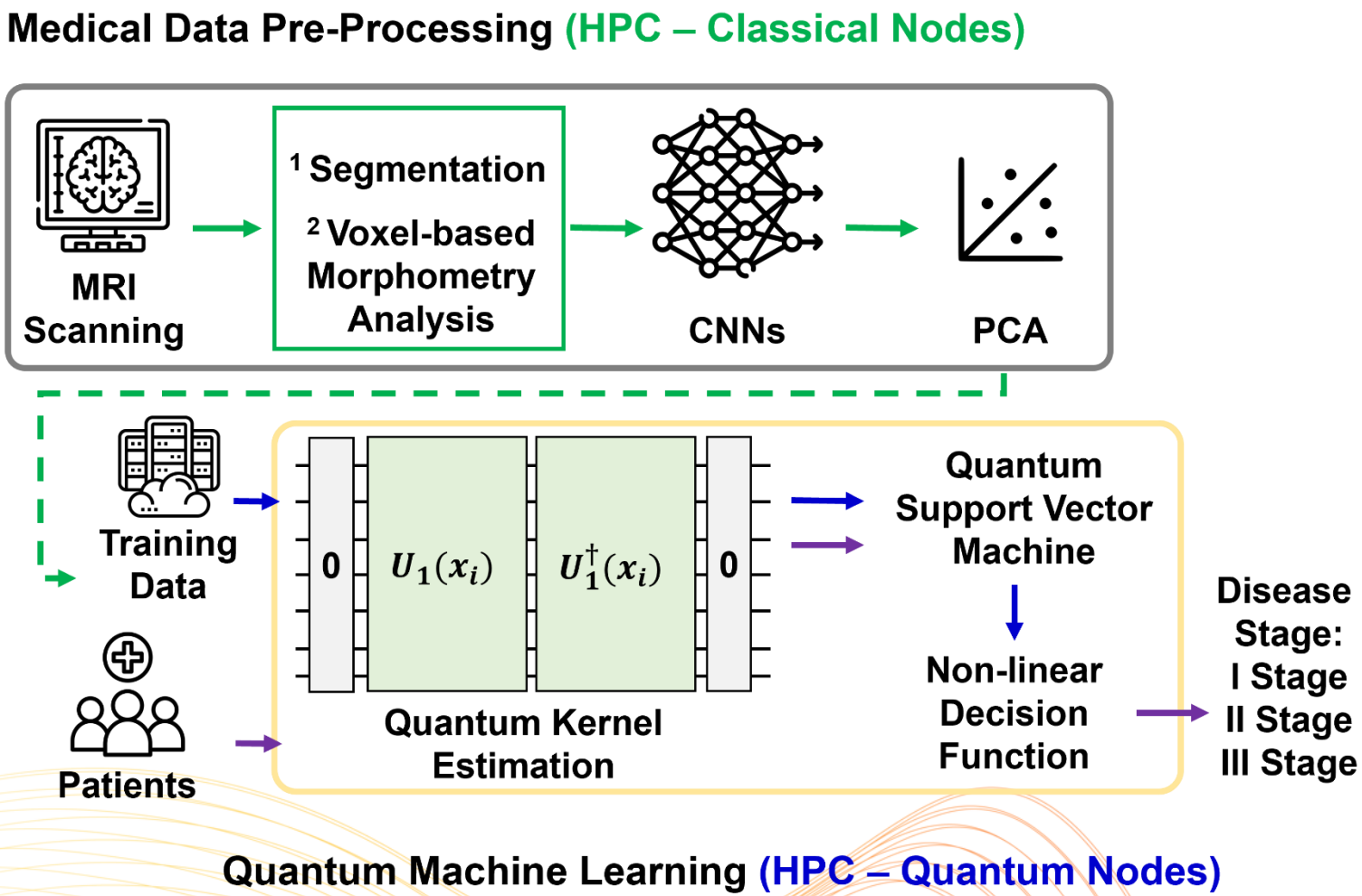
Quantum Kernel-based Long Short-Term Memory

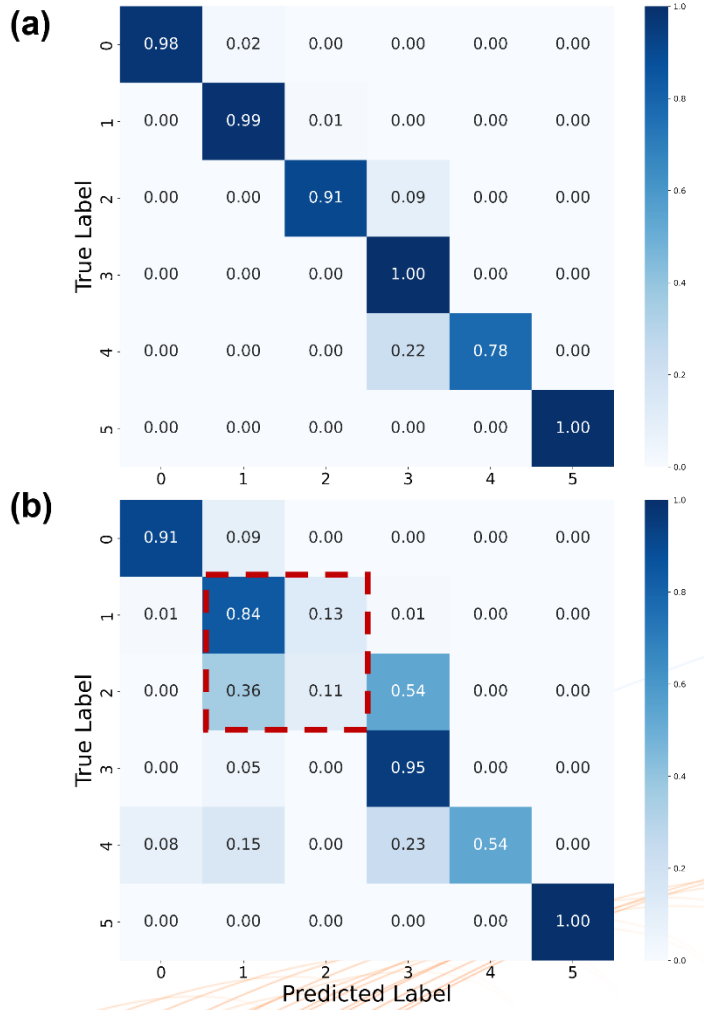
Comparative analysis of air quality prediction performance using classical LSTM and QK-LSTM models



"Quantum Kernel-Based Long Short-term Memory for Climate Time-Series Forecasting", IEEE QCNC 2025, https://arxiv.org/abs/2412.08851

Hybrid Quantum Machine Learning Pipeline for High-Dimensional Neuroimaging Data





"CompressedMediQ: Hybrid Quantum Machine Learning Pipeline for High-Dimensional Neuroimaging Data", IEEE ICASSPWS 2025, https://ieeexplore.ieee.org/document/11011218

Quantum Pointwise Convolution Networks

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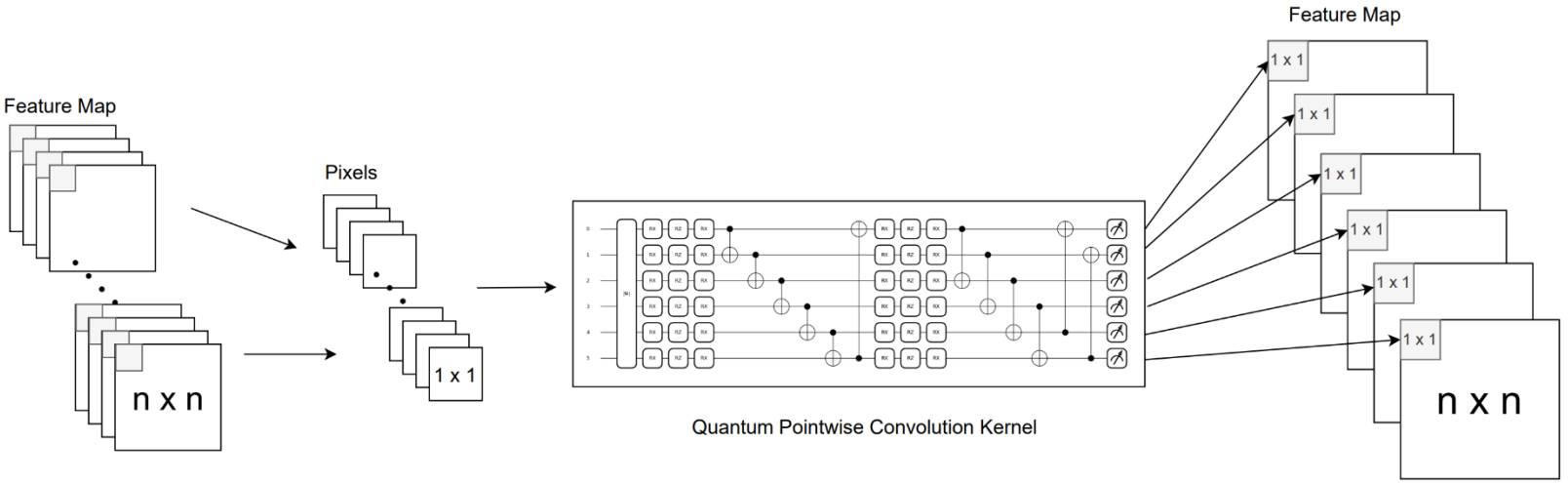
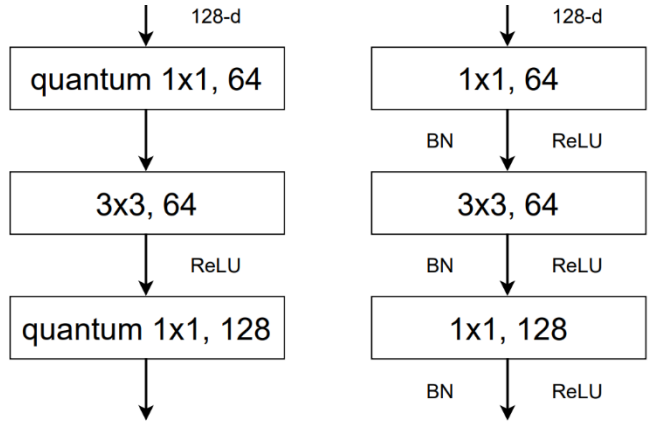
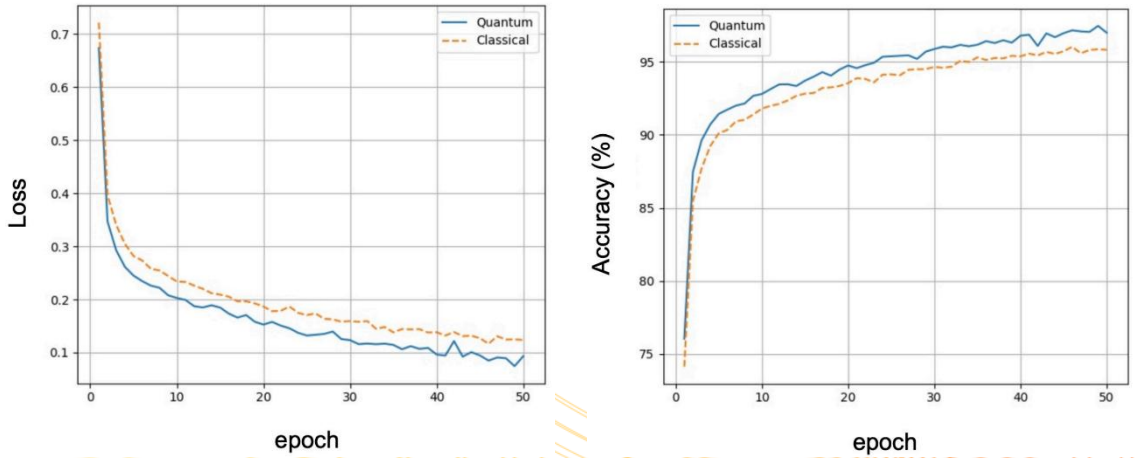
(a) Overview of the Quantum Pointwise Convolution Networks (QPWCNN)



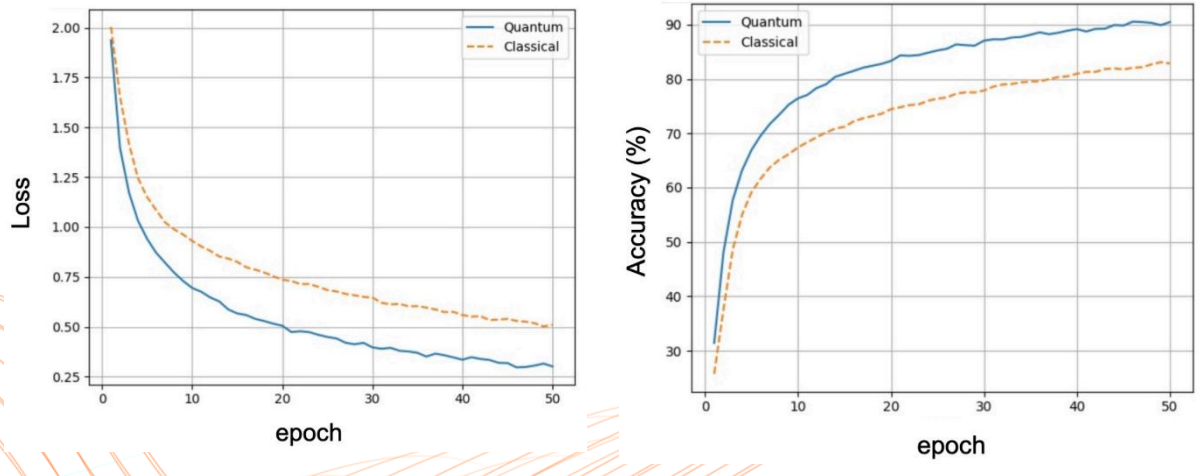
(b) With and without QPWCNN layer



(c) Fashion mnist Result



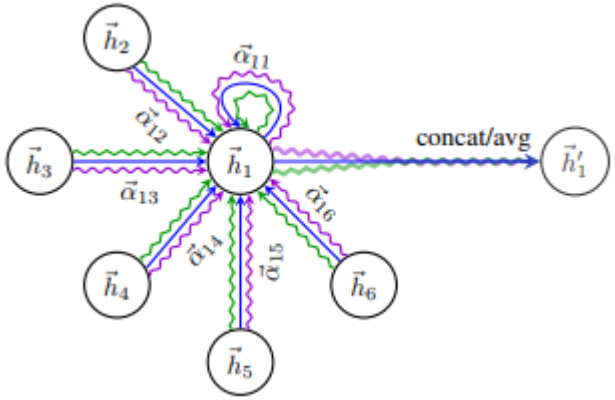
(d) Cifar10 Result



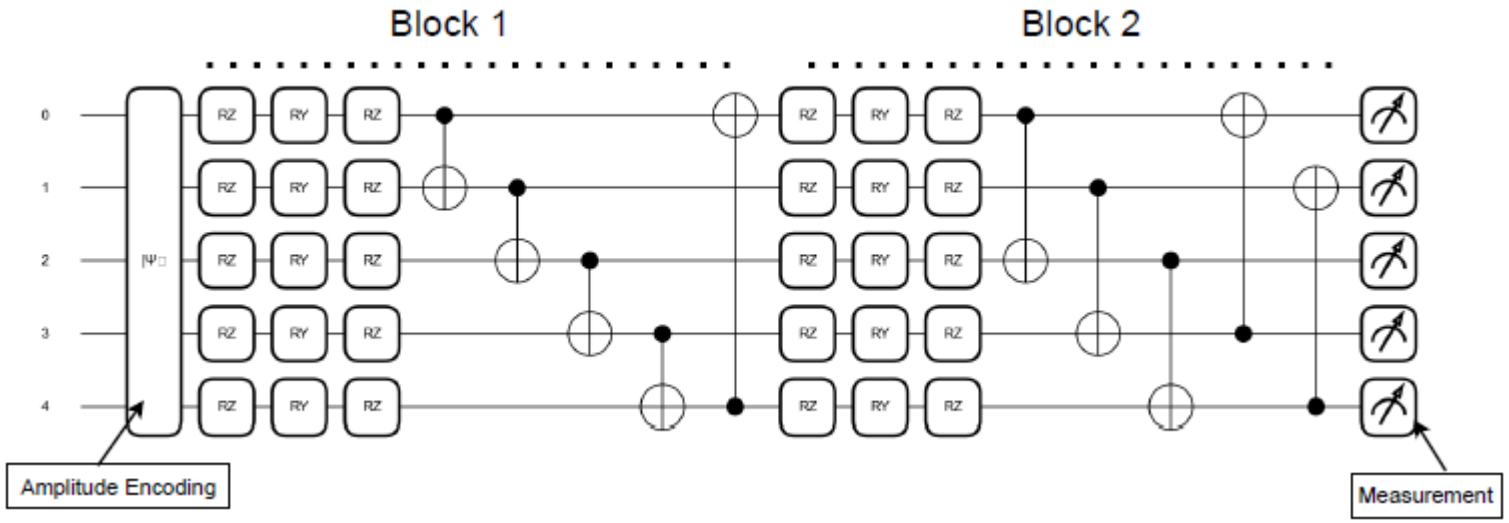
"Quantum Pointwise Convolution: A Flexible and Scalable Approach for Neural Network Enhancement", IEEE QCNC 2025, https://arxiv.org/abs/2412.01241

Quantum Graph Attention Network

A Novel Quantum Multi-Head Attention Mechanism for Graph Learning



An illustration of multi-head attention (with K = 3 heads) by node 1 on its neighborhood. Different arrow styles and colors denote independent attention computations. The aggregated features from each head are concatenated or averaged to obtain $\overrightarrow{h'_1}$. (https://arxiv.org/abs/1710.10903)



Example of a quantum circuit used in QGAT

"Quantum Graph Attention Network: A Novel Quantum Multi-Head Attention Mechanism for Graph Learning", https://arxiv.org/abs/2508.17630

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Benchmark results

Table 1: Accuracy (%) on transductive node classification benchmarks. All results are averaged over 5 runs; standard deviations are reported.

Model	Pubmed	ogbn-arxiv	ogbn-products
GAT [11]	78.1 ± 0.59	71.54 ± 0.3	79.04 ± 1.54
GATv2 [11]	78.5 ± 0.38	71.87 ± 0.25	80.63 ± 0.7
QGAT	$\mathbf{79.2 \pm 0.62}$	$\mathbf{73.62 \pm 0.42}$	$\mathbf{82.10 \pm 2.31}$

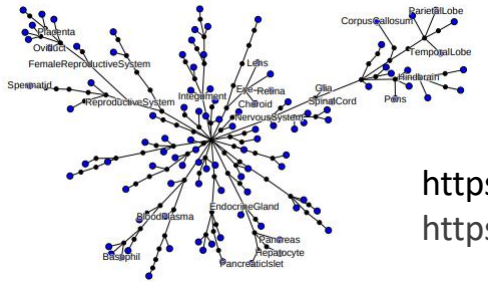
Table 2: Inductive node classification performance on PPI and ogbn-proteins. Metric: Micro-F1 (PPI) and ROC-AUC (ogbn-proteins). All results are averaged over 5 runs; standard deviations are reported.

Model	PPI (Micro-F1)	ogbn-proteins (ROC-AUC)
GAT [6]	97.3 ± 0.20	78.63 ± 1.62
GATv2	98.2 ± 0.25	$\mathbf{79.52 \pm 0.55}$ [11]
QGAT	$\mathbf{98.9 \pm 0.12}$	79.41 ± 0.21

Table 3: Link prediction performance on OGB benchmarks. Metric: Hits@50 (%) for *ogbl-collab*, and Mean Reciprocal Rank (MRR) for *ogbl-citation2*. All results are averaged over 5 runs; standard deviations are reported.

Model	ogbl-collab	ogbl-citation2
GAT [11]	46.63 ± 2.80	75.95 ± 1.31
GATv2 [11]	49.7 ± 3.08	80.14 ± 0.71
QGAT	$\mathbf{51.2 \pm 1.92}$	$\mathbf{82.2 \pm 1.27}$

https://arxiv.org/abs/2005.00687

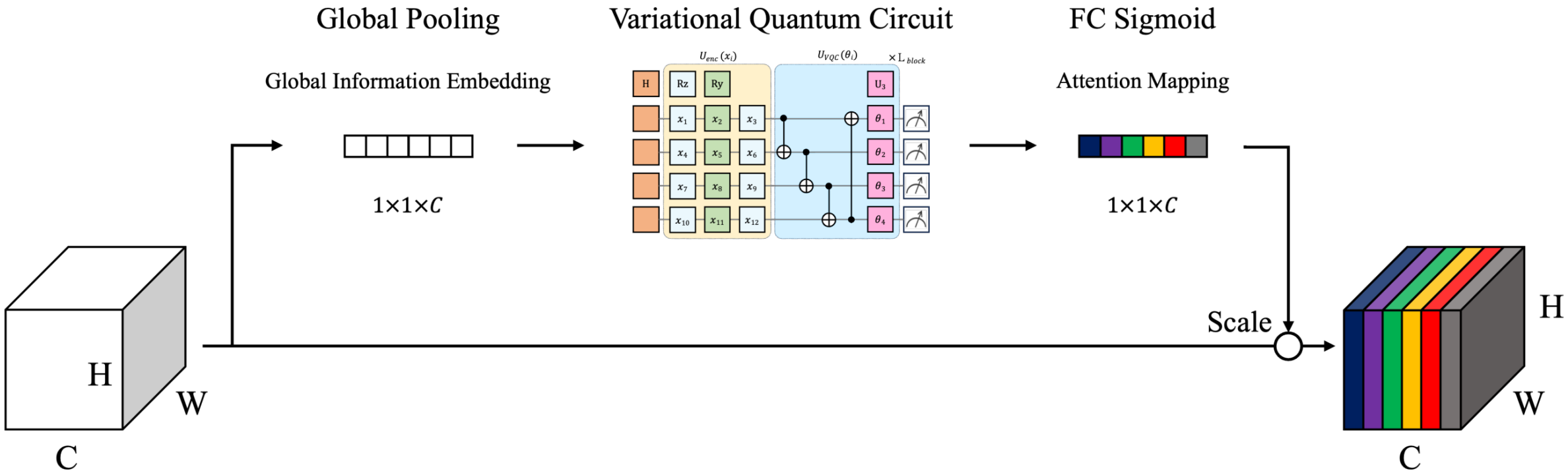


https://arxiv.org/abs/1707.04638
https://arxiv.org/abs/1706.02216

https://snap.stanford.edu/

"Quantum Graph Attention Network: A Novel Quantum Multi-Head Attention Mechanism for Graph Learning", https://arxiv.org/abs/2508.17630

Quantum Adaptive Excitation Network with Variational Quantum Circuits for Channel Attention



IEEE Quantum Week 2025, https://arxiv.org/abs/2507.11217

Quantum Adaptive Excitation Network with Variational Quantum Circuits for Channel Attention

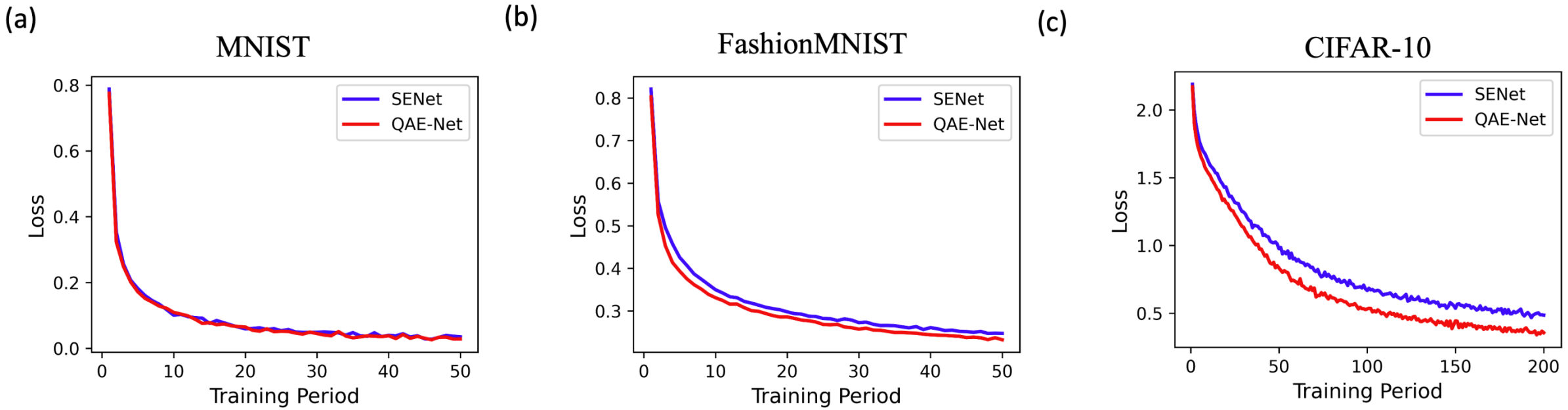


Fig. 3: Training progression of QAE-Net as visualized through the Cross-Entropy (CE) Loss across epochs for three different datasets: (a) MNIST, (b) FashionMNIST, and (c) CIFAR-10.

Quantum Adaptive Excitation Network with Variational Quantum Circuits for Channel Attention

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TABLE I: Comparative Performance of SENet and QAE-Net Across Benchmark Datasets (Ch. = Channels). All QAE-Net configurations employed 4 qubits.

Dataset	Method	Ch.	Epoch	Params	Acc. (%)
MNIST	SENet [3]	1	50	39,602	97.9
	QAE-Net	1	50	**39,366**	**98.0**
F-MNIST	SENet [3]	1	50	39,602	91.0
	QAE-Net	1	50	**39,366**	**91.3**
CIFAR-10	SENet [3]	3	200	142,634	76.72
	QAE-Net	3	200	**142,570**	**89.08**

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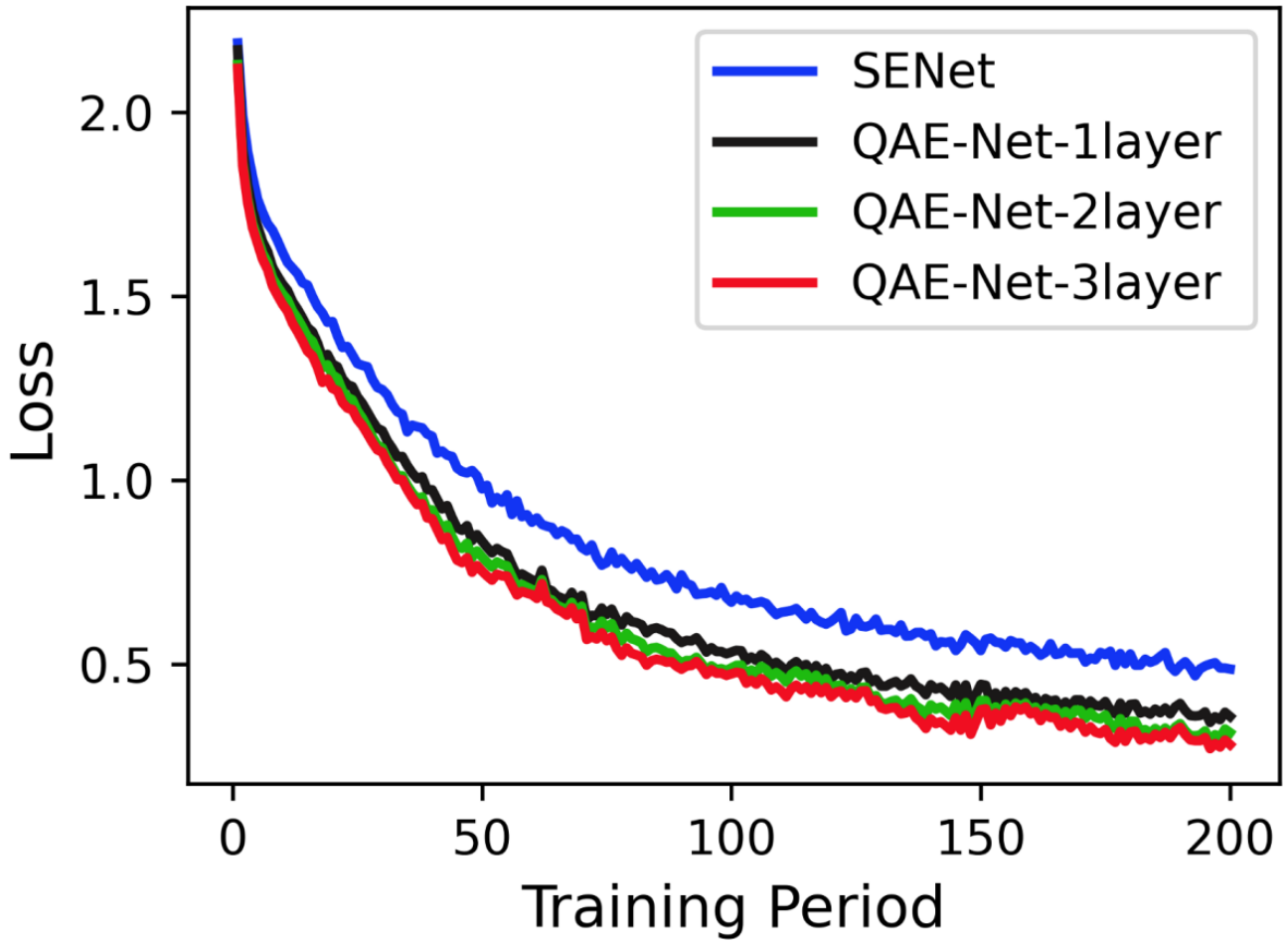

Metric	SENet	QAE-Net (1 layer)	QAE-Net (2 layers)	QAE-Net (3 layers)
Epochs	200	200	200	200
Accuracy (%)	76.72	89.08	90.10	**92.30**
Qubits	–	4	4	4
Learning Rate	0.001	0.001	0.001	0.001

Collaborators

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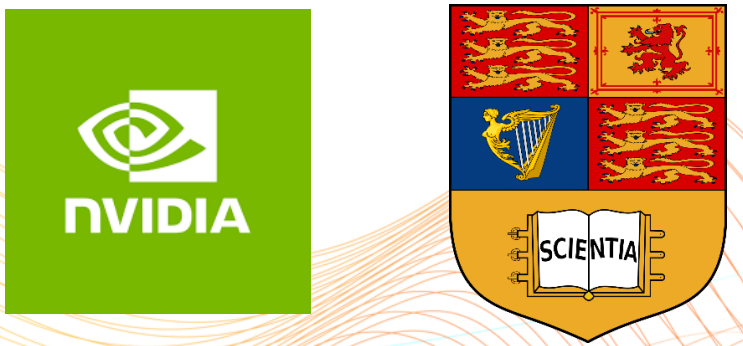

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