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NEC SX-Aurora TSUBASA Update

May 2021

\Orchestrating a brighter world

NEC creates the social values of safety, security, fairness and efficiency to promote a more sustainable world where everyone has the chance to reach their full potential.

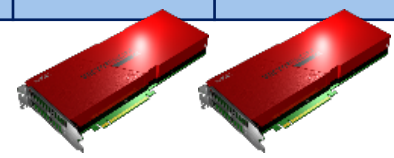
Agenda

1. SX-Aurora TSUBASA Vector Engine Intro
2. SX-Aurora TSUBASA for Computational Fluid Dynamics
3. SX-Aurora TSUBASA for Combinatorial Problems

SX-Aurora TSUBASA Vector Engine Intro

SX-Aurora TSUBASA - The latest in SX Vector computer series

Model	 SX-1/2	 SX-3	 SX-4	 SX-5	 SX-6	 SX-7	 SX-8/8R	 SX-9	 SX-ACE	 SX-Aurora TSUBASA	 SX-Aurora TSUBASA Gen2
Year	1983	1989	1994	1998	2001	2002	2004	2007	2013	2018	2020
Technology	Bipolar	Bipolar	350 nm	250 nm	150 nm	150 nm	90 nm	65 nm	28 nm	16 nm	16 nm
CPU frequency	166 MHz	340 MHz	125 MHz	250 MHz	500 MHz	552 MHz	1.0 GHz	3.2 GHz	1.0 GHz	~1.6 GHz	~1.6 GHz
CPU performance	1.3 GF	5.5 GF	2.0 GF	8.0 GF	8.0 GF	8.8 GF	16.0 GF	102.4 GF	256.0 GF	~2.45 TF	~3.07 TF
CPU Memory bandwidth	10.7 GB/s	12.8 GB/s	16.0 GB/s	64.0 GB/s	32.0 GB/s	35.3 GB/s	64.0 GB/s	256.0 GB/s	256.0 GB/s	~1.22TB/s	~1.53TB/s

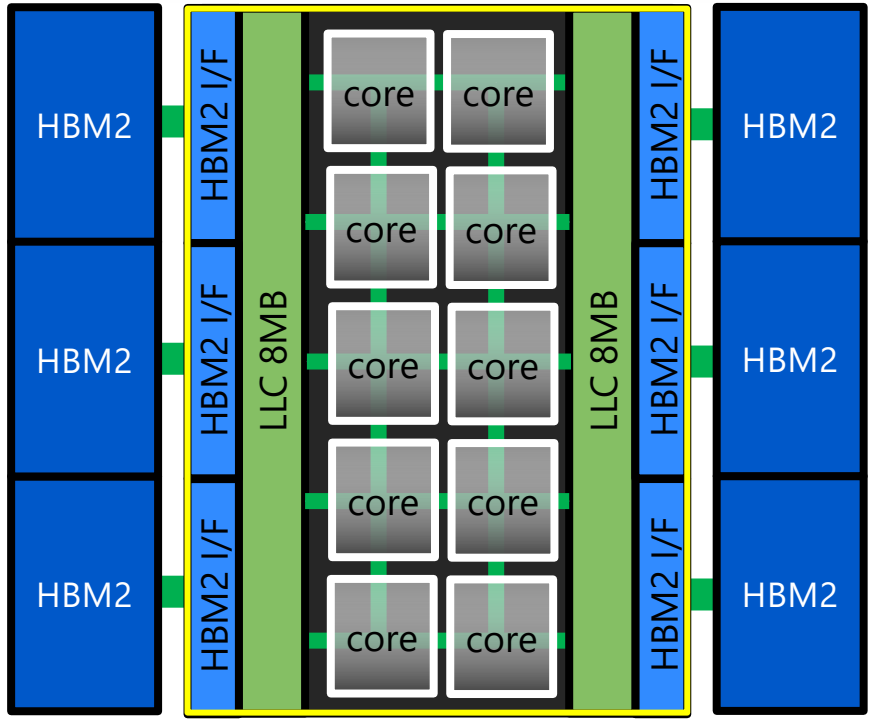


VE10
VE10E

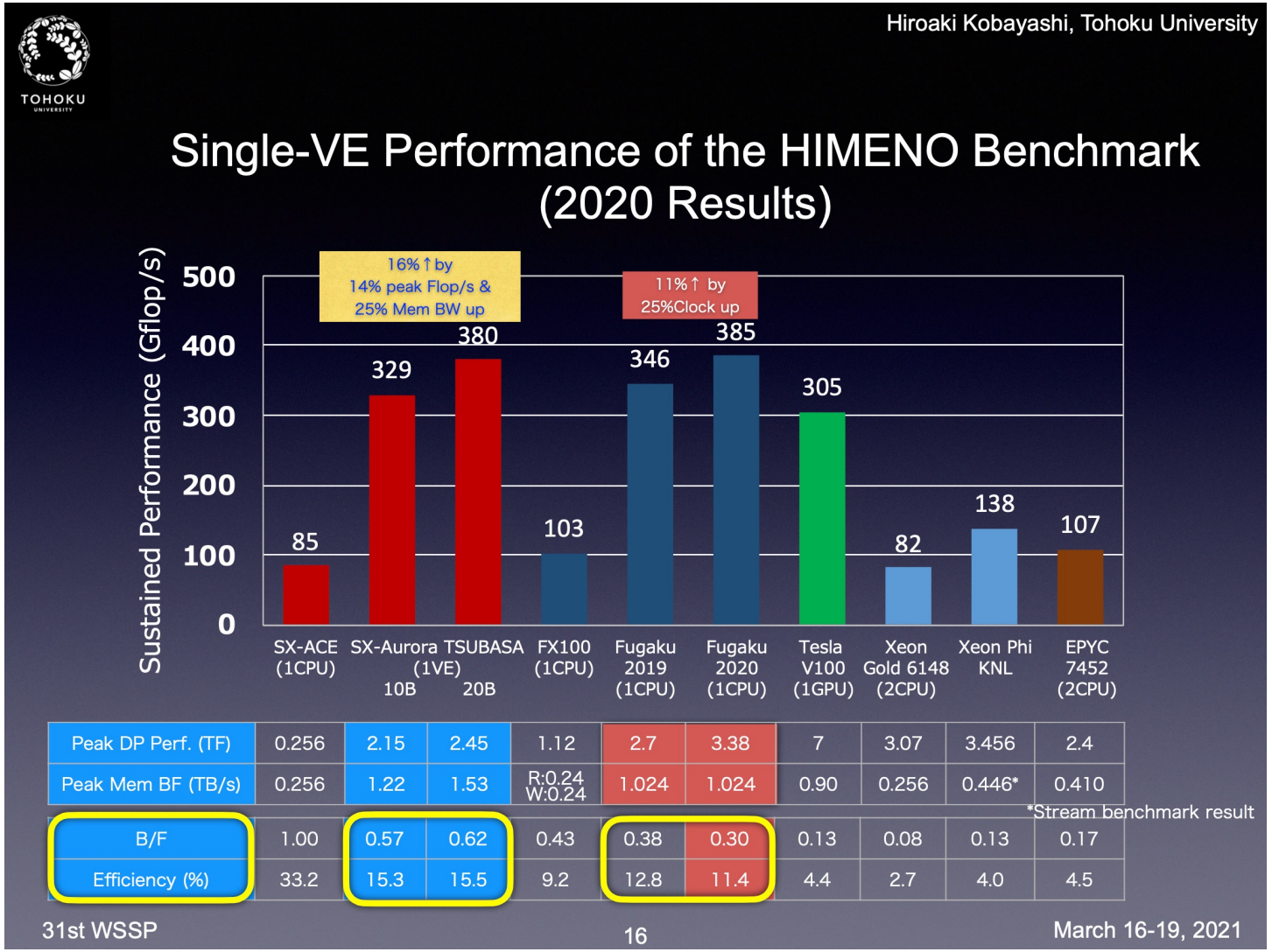
VE20

VE20 Specifications

Processor Version	Type 20A	Type 20B
Cores/processor	10	8
Core performance	307GF (DP) 614GF (SP)	
Processor performance	3.07TF (DP) 6.14TF (SP)	2.45TF (DP) 4.91TF (SP)
Cache capacity	16MB	
Cache bandwidth	3TB/s	
Cache Function	Software Controllable	
Memory capacity	48GB	
Memory bandwidth	1.53TB/s	
Power	~300W (TDP) ~200W (Application)	



SX-Aurora TSUBASA Key Performance Capabilities

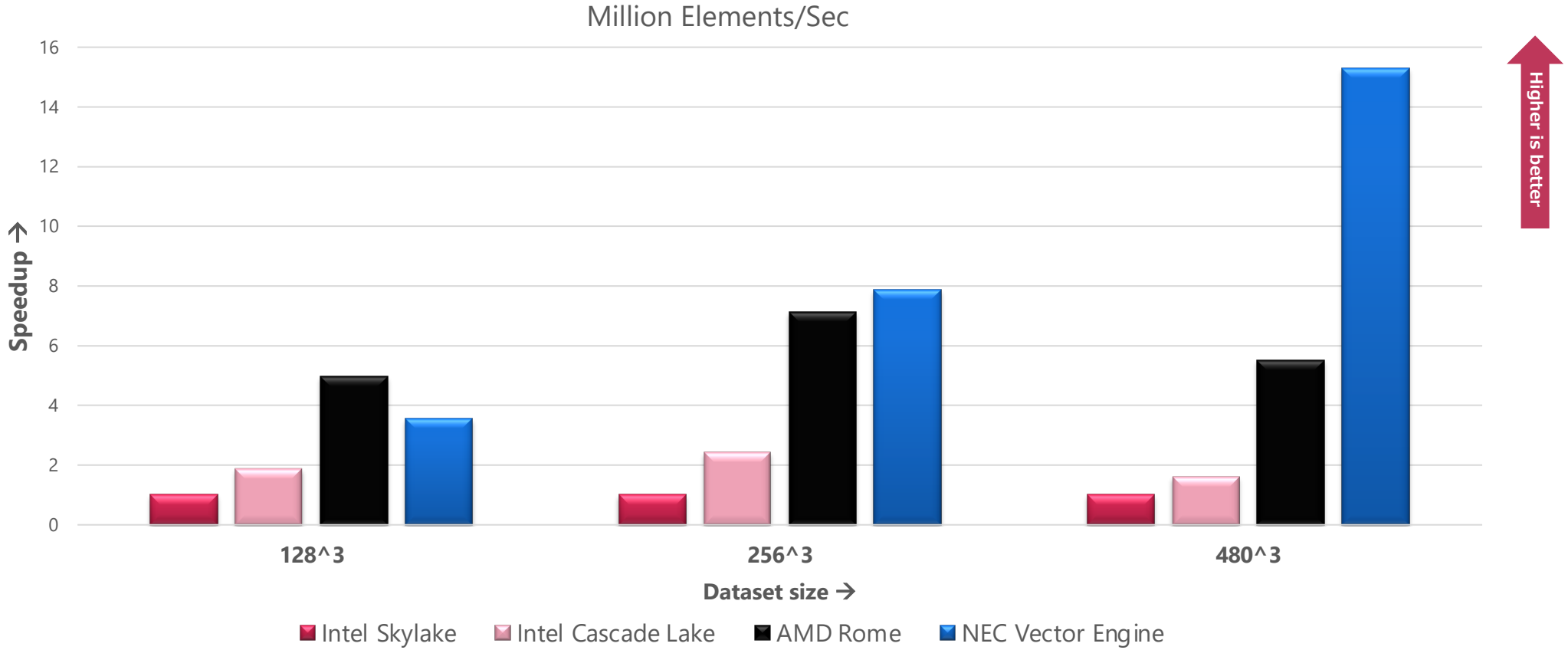


SX-Aurora TSUBASA for Computational Fluid Dynamics

CFD with SX-Aurora TSUBASA

- Computational Fluid Dynamics (CFD) simulations of various applications involve intensive computations that require large amounts of memory and processing time to achieve accurate results in a quick time frame.
- Laboratories for Computational Physics and Fluid Dynamics at the US Naval Research Laboratory (NRL) has special interests in exploring and evaluating emerging architectures for HPC applications.
- Since most of the legacy CFD vector code & their descendants are still in use by DoD, NRL expected that these codes can achieve improved performance without time-consuming & labor-intensive refactoring required to run on a new architecture.
- Thus, NRL aimed to accelerate a legacy CFD solver named FDL3DI on SX-Aurora TSUBASA. FDL3DI was originally developed at US Air Force Research Laboratory in 1990s and still retains its vector-friendly code structure.
- Some applications of FDL3DI include wing-vortex aerodynamics, flow control for laminar flow airfoils and shock/boundary layer intersection in front of canonical shapes.

FDL3DI Solver with SX-Aurora TSUBASA



- Original version of FDL3DI executed on SX-Aurora TSUBASA without any modification.
- For the optimization process, most time-consuming routines were optimized by:
  - vectorizing the loops that were not originally vectorized by combining the nested loops wherever possible
  - manually assigning the participating arrays to vector registers to minimize time-consuming copies from main memory

SX-Aurora TSUBASA for Combinatorial Problems

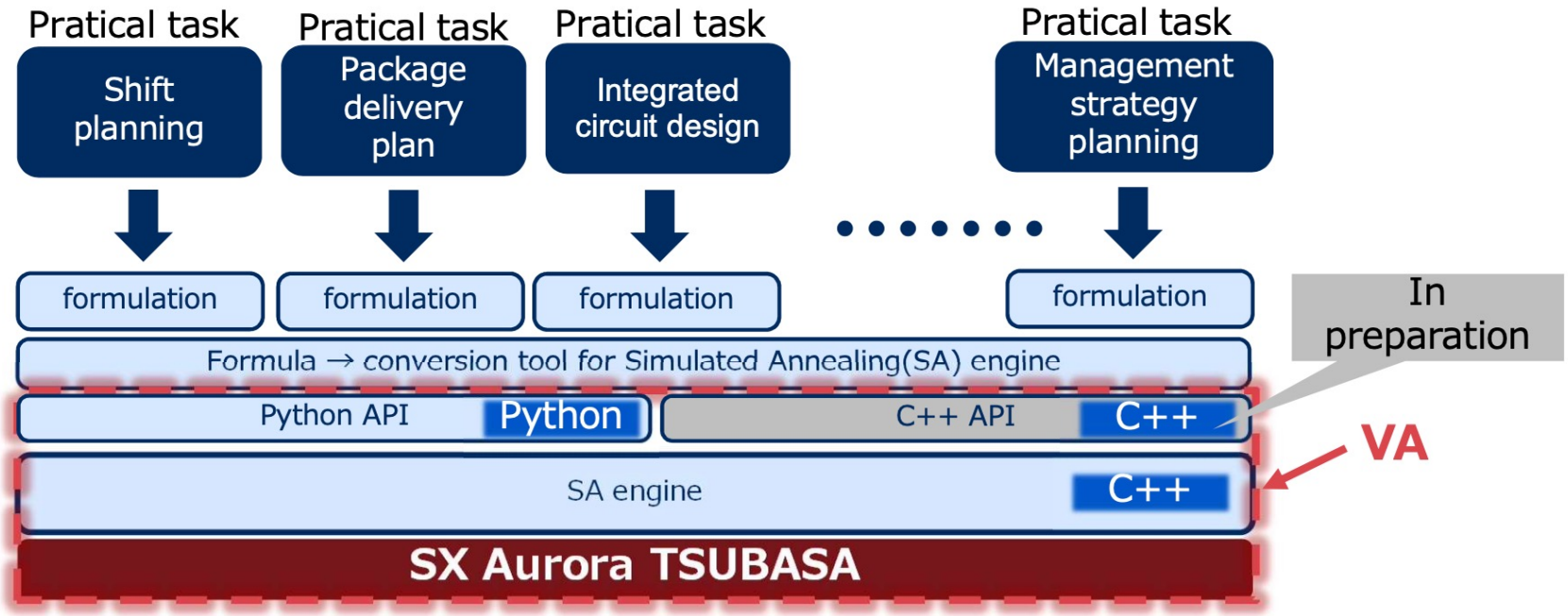
Combinatorial Problems

- Combinatorial problems arise in multiple areas of computer science and application domains.
- Examples: Finding shortest/cheapest round trips(TSP), planning/scheduling, Supply Chain Optimization, Circuit design, Protein Structure Prediction etc.
- Their solution space is typically too large to search exhaustively using brute force.
- Annealing algorithms like Simulated Annealing and Quantum Annealing accelerate the solution of combinatorial problems.
  - Simulated Annealing (SA)
    - Probabilistically searching the optimal solution
  - Quantum Annealing (QA)
    - Searching the optimal solution using quantum effect
- In the annealing algorithms, the combinatorial problem is represented by a quadratic unconstrained binary optimization (QUBO) problem.

Simulated Annealing with SX-Aurora TSUBASA

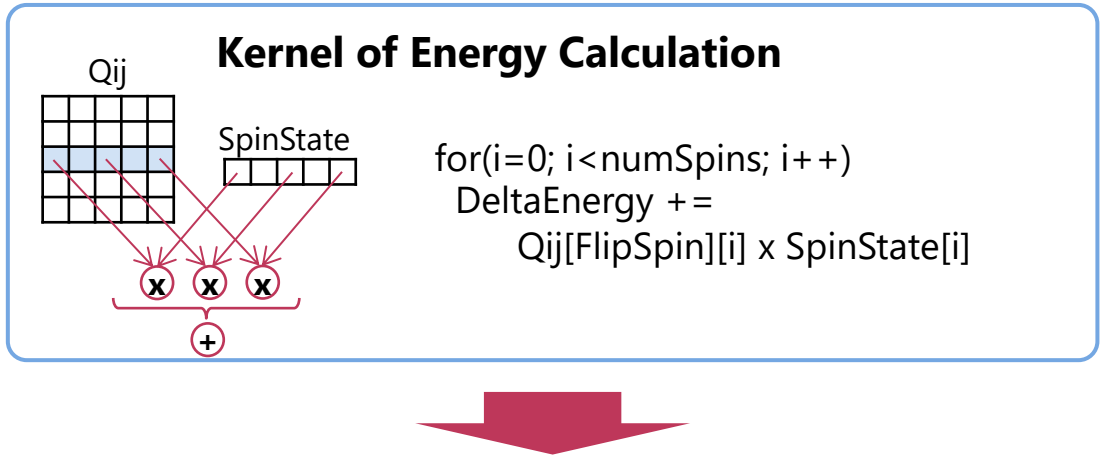
- NEC has developed SX-Aurora TSUBASA optimized Simulated Annealing(SA) Engine for solving combinatorial problems.

Input	QUBO format
Problem Size	Up to 100K Qubit Can soon be extended to multiple Vector Engine cards
Connection	32bit floating point, full connection
Algorithm	Includes External Constraint extension to improve the results



Why Simulated Annealing with SX-Aurora TSBUASA?

- Simulated Annealing (of QUBO) : Easily Vectorizable
- Kernel Computation : Requires high memory bandwidth

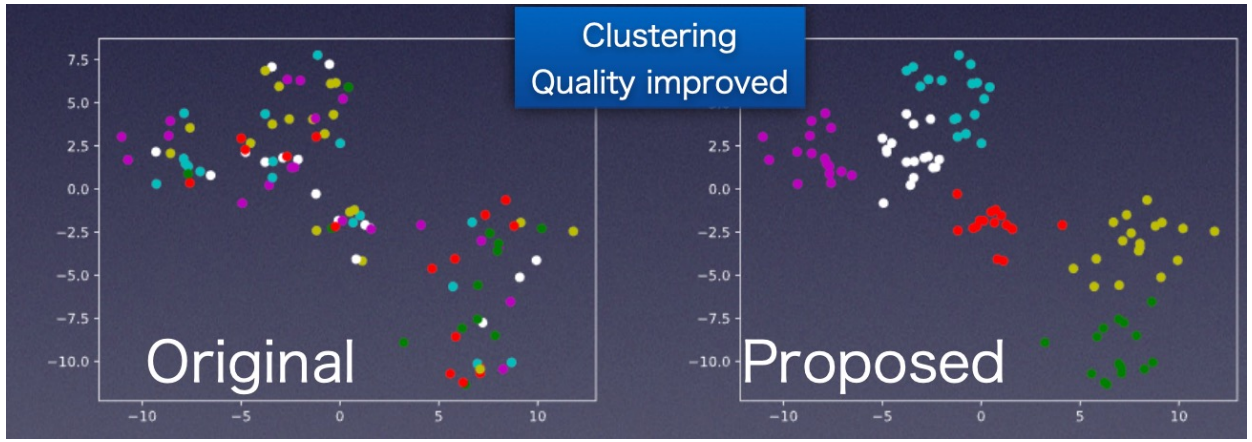


Suitable for SX-Aurora TSUBASA

- Size of the problem (that corresponds to qubit) : Memory size limited
  - 48GB per card = 100K qubit (fully connected)
  - Can be complementary with the both the real quantum machines and CPUs for larger problem

Combinatorial Clustering with NEC Simulated Annealing Engine

- Data Clustering is a well-known method to analyze data for data mining such as pattern, recognition, image analysis, machine learning.
- Combinatorial Clustering is the clustering that can be defined as combinatorial problem for quantum and simulated annealing acceleration.
- However, Combinatorial Clustering quality degrades on both quantum computers and CPUs when data points increase.
- NEC SA Engine utilizes an extension named Simulated Annealing External Constraint (SAEC) to improve the clustering quality by several magnitudes*.



*Sources:
1. 'Combinatorial Clustering Based on an Externally-Defined One-Hot Constraint' white paper
by Masahito Kumagai, Kazuhiko Komatasu, Fumiyo Takano, Takuya Araki, Masayuki Sato, Hiroaki Kobayashi
2. 'The New Era of Hybrid-Computing on and with SX-Aurora TSUBASA: Vector-Scalar to Vector-Digital Annealing, to Vector-Quantum Annealing'
by Hiroaki Kobayashi, Tohoku University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