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shaping tomorrow with you

Supercomputer "Fugaku" and Beyond

(Translated from Japanese presentation slides)

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From “K computer” to Supercomputer “Fugaku”

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- K computer was shut down in August, 2019 after 7 years of operation
- The last rack of Supercomputer “Fugaku” was delivered in May 2020
  - Software adjustment is ongoing for the general use scheduled in FY2021
- Fugaku tech FX1000 & FX700 are GA already, and A64FX CPU is supplied to HPE

Benchmark Results and “Fugaku” Specification

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		K computer, SPARC64 VIIIfx	Fugaku, A64FX
System spec.	Instruction set architecture	SPARC-V9 HPC-ACE	Armv8.2-A SVE 512bit
	Double precision performance	11.28 Petaflops	537 Petaflops
	Half precision (AI) performance	-	2.15 Exaflops in half precision
	Total memory bandwidth	5.64 PB/s	163 PB/s
	Interconnect	Tofu interconnect	Tofu interconnect D
SC20	TOP500 (Petaflops)	10.51 (#1 at June/Nov. of 2011)	415.53 → **442.01** (#1)
	HPCG (Petaflops)	0.6027 (#1 Nov. 2016~Nov. 2017)	13.36 → **16.00** (#1)
	HPL-AI (Exaflops)	—	1.42 → **2.00** (#1)
	Graph500 (TTEPS)	31.302 (2014~2019.6 #1)	70.98 → **102.95** (#1)

- TOP500: Performance of solving the linear equation (dense matrix) Ax = b, which is common in science and engineering. The standard performance indicator for supercomputers
- HPCG : Performance of solving the linear equation with sparse coefficient matrix using Conjugate Gradient method
- HPL-AI: Performance of solving the linear equation utilizing lower precision floating point calc., like fp16, which AI often utilizes
- Graph500: Performance of big data processing. Integer and memory access speed related to the graph search/traverse are evaluated

Technical Innovations and Features of “Fugaku”

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Faster applications: Leading-edge technology

- The world's first CPU w/ Arm’s HPC extension, SVE, for which Fujitsu collaborated as a lead partner
- An arithmetic unit (512 bit SIMD) with 4x of K and half-precision (FP16) used in AI
- HBM2 for high memory BW
- Tofu interconnect D for efficient massively parallel processing (Enhanced Tofu for K)

Energy efficient and reliable: in-house hardware and software

- Original CPU, system, and software for stable and improved operation of large systems
- Efficient hardware with software control of power-saving features (power knob)
- Fujitsu's CPU design and leading-edge Si-tech to achieve world-class power efficiency

Ease and breadth of use: Adoption of industry standards

- Original CPU "A64FX" using Arm architecture widely used in smartphones and IOT devices
- Red Hat Enterprise Linux (RHEL 8), which is widely used for servers, etc.

“Fugaku” and Fujitsu Commercial Supercomputers

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Lineup of supercomputers equipped with A64FX CPU

Fugaku “富岳”

Developed with RIKEN

- 150k nodes
- Water-cooled
- Tofu interconnect D
- Fujitsu / RIKEN original software

FUJITSU Supercomputer PRIMEHPC

PRIMEHPC FX1000
for highly scalable system

- 384 nodes/ Rack
- Water-cooled
- Tofu interconnect D
- Fujitsu original software

PRIMEHPC FX700
easier adoption w/ de facto tech

- 8 nodes/ 2U Chassis
- Air-cooled
- InfiniBand
- OSS/ ISV software

A64FX Performance and Power using OSS Real Apps

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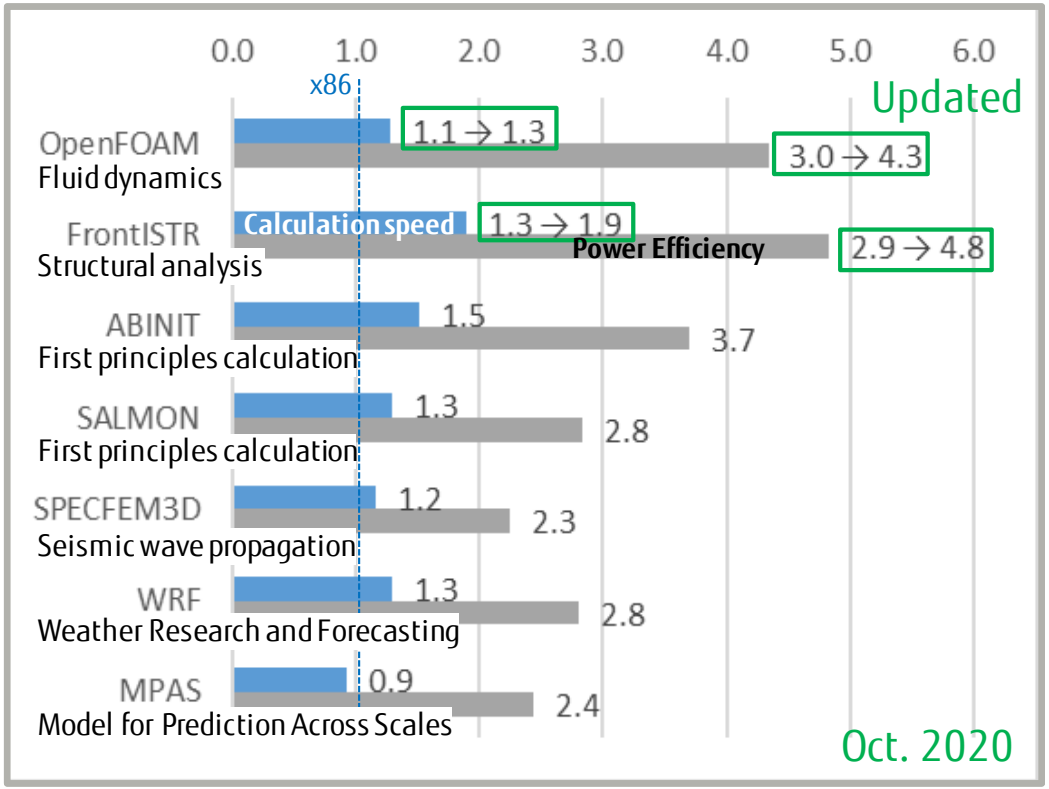
Performance scaling of a A64FX over 2x x86



- Latest x86 and A64FX w/ the same number of cores*
  - Up to 1.9 times faster
  - Up to 4.8 times lower energy

* A64FX : 48 cores ×1 CPU (2.2 GHz)
x86 CPU : 24 cores ×2 CPU (2.9 GHz)

- Scalable performance obtained by
  - Enhanced microarchitecture for HPC
  - Energy-saving design & implementation

Commercial Applications

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- Fujitsu works with vendors to make commercial apps available for FX1000, also for FX700 and Fugaku with binary compatibility

(as of Nov. 2020)

Available	In a research & development phase

Engineering (Structural analysis, Fluid dynamics and Electronics)

Available in Q4 '20
- LS-DYNA (by Ansys)

Available in Oct. '20
- Poynting (by Fujitsu Limited)

- ADVENTURECluster (by Allied Engineering Co.)
- Altair Radioss™ (by Altair Engineering, Inc.)
- Ansys Fluent (by Ansys)
- CONVERGE CFD SOFTWARE (by Convergent Science)
- HELYX® (by ENGYS Ltd. & VINAS Co., Ltd.)
- JMAG® Simulation Technology for Electromechanical Design (by JSOL Corporation)
- Marc (by HEXAGON / MSC Software)
- scFLOW (by HEXAGON / Cradle)
- Simcenter STAR-CCM+ (by Siemens Industry Software Inc.)

Chemistry*

Available for FX1000
- Amber
- Gaussian16 (by Gaussian, Inc.)

- VASP

*Collaboration with Australian National University

- VPS (PAM-CRASH) (by ESI Group)

Solving the Social Issues by Supercomputer

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~ Social Issues ~

Social issues

- Health and longevity
- Safe and secure society
- Climate problem
- Industrial competitiveness
- Sustainable energy
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Specific area

- **Life science**
- **Disaster prevention and the environment**
- **Manufacturing**
- **Energy**

Future

Now

Past

【Simulation】

- Fluid dynamics
- Crash and structure
- Materials
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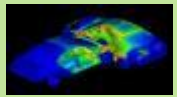

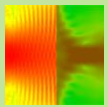

【Data analysis】

- AI(Deep Learning)
- Big data analysis
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~ Supercomputer ~

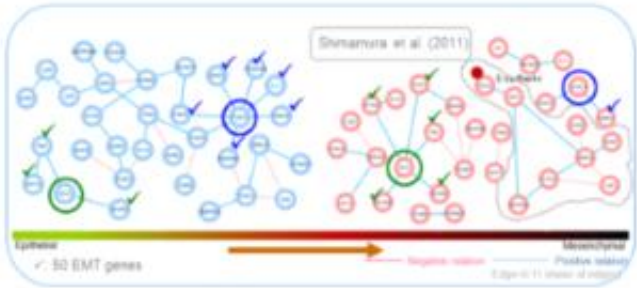
Supercomputer will be used as the infrastructure to support solving the social issues & digital transformation

Fugaku Achievement Acceleration Program

- Project theme
  - Elucidation of the cause and diversity of cancer using large-scale data analysis and AI technology
- Research representative
  - M&D Data Science Center

    Tokyo Medical and Dental University (TMDU)

    Director, Satoru Miyano



Heewon Park, Koji Maruhashi, Rui Yamaguchi, Seiya Imoto, Satoru Miyano. Global gene network exploration based on explainable artificial intelligence approach. PLoS ONE (2020)

Fujitsu and Tokyo Medical and Dental University Leverage World's Fastest Supercomputer to Perform Cancer Gene Network Analysis in Less than a Day

Tokyo Medical and Dental University,Fujitsu Laboratories Ltd.

News Facts:

- Tokyo Medical and Dental University and Fujitsu Laboratories Limited mark new milestone in the field of life science research, shortening the calculation period for cancer gene network analysis with explainable AI technology and world's fastest supercomputer
- Breakthrough the result of TMDU's collection and management of genetic data and its interpretation and verification insights of AI findings, with data processing provided by the world's fastest supercomputer, Fugaku, and Fujitsu's explainable AI technology
- New approach will be applied to the analysis of more large-scale data generated by genome sequence analysis technology leveraging Fugaku, and the results will be interpreted with explainable AI, to help achieve some of the world's most advanced cancer research

Tokyo, November 10, 2020

Tokyo Medical and Dental University (TMDU) and Fujitsu Laboratories Limited have recently completed, in less than a day, estimation of the network that represents the influence relationship between genes and prediction of their relationship with infiltration and metastasis based on genes highly likely to be involved in cancer development. TMDU and Fujitsu achieved this leveraging Fujitsu Laboratories' explainable AI technology "Deep Tensor"(1) with the world's fastest supercomputer, Fugaku(2), which was jointly developed by RIKEN and Fujitsu. The project was conceived under the theme of "elucidation of the cause and diversity of cancer using large-scale data analysis and AI technology" as part of the supercomputer Fugaku achievement acceleration program(3) being promoted by Japan's Ministry of Education, Culture, Sports, Science and Technology from May 2020 to March 2023.

https://www.fujitsu.com/global/about/resources/news/press-releases/2020/1110-01.html

Global Adoption and Partnership

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- Commercial products
  - PRIMEHPC FX series
    - GENCI, France
    - University of Regensburg, Germany
    - Sandia National Laboratories, USA etc.
  - HPE Apollo 80 with A64FX CPU
    - The Leibniz Supercomputing Centre, Germany
    - University of Bristol, GB
    - Los Alamos National Laboratory, USA etc.
- Collaboration with overseas leading research institutes
  - Research collaboration
    - Barcelona Supercomputing Center, Spain
  - Provides evaluation environment
    - Jülich Supercomputing Centre, Germany, EPCC, GB, etc.

PRIMEHPC FX700

FX1000

HPE Apollo 80 System

Apps evaluation and ecosystem development utilizing A64FX Arm SVE

Summary

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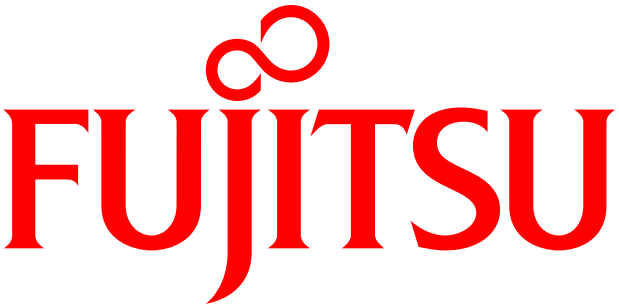
- Flagship supercomputer "Fugaku" is designed and developed thru co-design with RIKEN effort and Fujitsu's full range of over 40 years experience of development on hardware and software of supercomputers
- Ranked #1 in four major benchmarks, two consecutive rounds in June & Nov. 2020, by design and implementation for high "Fugaku" application performance
- The world's fastest "Fugaku" performance is expected to help realize Society 5.0, which requires high speed simulation and AI capabilities
  - "Advanced use for COVID-19 related research" and "Elucidation of the cause and diversity of cancer", for example
- Developing *Fugaku tech*, A64FX and PRIMEHPC FX1000 & FX700, into business globally

Fujitsu aims to provide a prosperous future through the fruits of supercomputers around the world. With the advent of the digital age, high speed simulation with AI capable supercomputers will be widely used in many fields.



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