Best Engine

Vol. 15

Special Feature

Special Interview
Oxford Quantum Circuits Limited (OQC) of the UK

How Close Are Quantum Computers to Practical Use?

Oxford Quantum Circuits Limited
Hitoshi Kawahara
Associate Principal, Technology Research Department No. 2, Advanced IT Strategy Division
ITOCHU Techno-Solutions Corporation

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Vol. 15

Cover illustration by
Miki Mohri

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The Four Seasons of IT

Evolution and Diversity

In recent years, a new conceptualization of the human body's mechanisms has emerged.

Up until now, we have believed that the organs in the human body act on orders from the brain to maintain life and health. However, in reality we could also say that the organs form networks with each other and communicate directly while supporting each other to make biological systems work. It seems to me that this new insight could become a major clue to rethinking the way corporate business should be managed.

We spoke about CTC 5.0 in the previous two issues, but the goal of that is to evolve and survive. In today's world with the environment surrounding companies and the social landscape changing in complex ways at blinding speed, it feels inevitable that organizations must transform from "vertical hierarchies" that await directions from managers, to more "horizontally interconnected" organizations.

Companies are congregations of people. Evolution arises through mutual influences within the group. Just as various organs and cells in the human body endlessly exchange messages, workplaces and individual employees also constantly exchange information across organizational boundaries and dynamically take action according to the situation. It is said that larger companies struggle to evolve, but having good diversity in place can be considered a major advantage that facilitates evolution.

If we want to evolve our company to survive in an age of unpredictability and uncertainty, as the people who comprise the company, we must first open our eyes to the idea of evolving ourselves. The key for the CTC Group to evolve the right way is for each and every one of us to refine our own specialties, combine knowledge and abilities with other employees, influence each other, and raise our intellectual productivity, with evolution in mind.

From global warming to the tense state of world affairs, energy depletion, food shortages, and more, we find ourselves confronted with unprecedented social problems. Addressing these will require us to reconsider how services and solutions should exist, using not only convenience and efficiency as measurements, but also by thinking about "what is true happiness?" and "how should society be in the future?" from philosophical, ethical, aesthetic, and other perspectives.

In order to make a better tomorrow for our customers and society, we will work on upgrading ourselves to CTC 5.0 with a fresh new organizational framework in fiscal 2024.

Ichiro Tsuge

Chairman
ITOCHU Techno-Solutions Corporation

Special Feature

Special Interview
Oxford Quantum Circuits Limited (OQC) of the UK

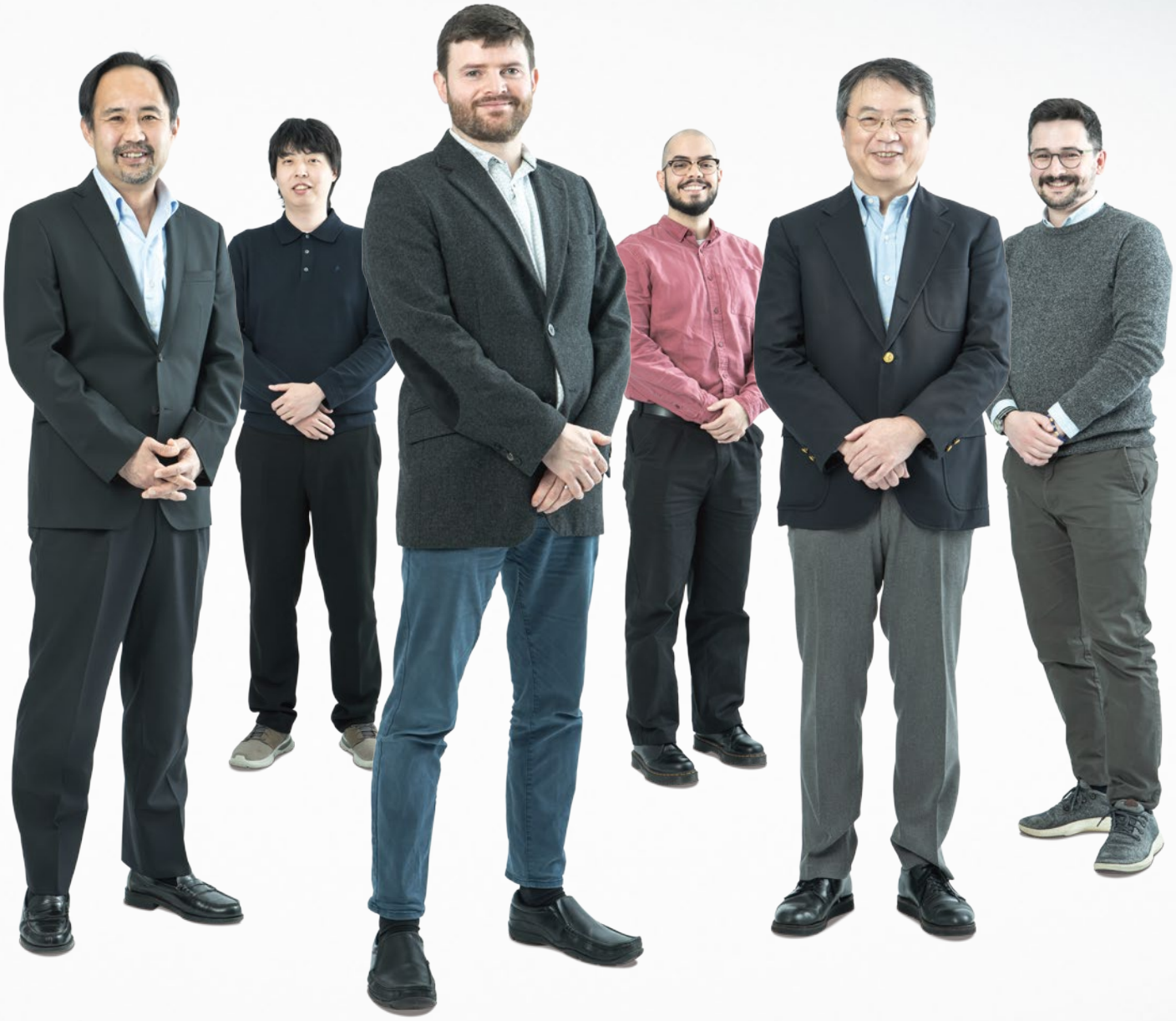
How Close Are Quantum Computers to Practical Use?

Oxford Quantum Circuits Limited (OQC) of the UK, a world leader in quantum computer development, has a 32-qubit quantum computer named “OQC Toshiko” installed at a colocation data center in Tokyo, which it deployed for commercial use in November 2023. Services offering the unprecedented commercial use of quantum computers are now available via Japan. Meanwhile, CTC announced a partnership with OQC in October 2023. We will be working together to develop quantum algorithms going forward. What kind of a company is OQC, and to what degree have quantum computers become a reality? And how will the partnership between OQC and CTC develop from here? In February 2024, we asked these questions and more to members of OQC visiting Japan and Hitoshi Kawahara who heads up quantum computer technology at CTC.

Coverage and text by Yuki Kondo

Oxford Quantum Circuits Limited

Hitoshi Kawahara
Associate Principal, Technology Research Department No. 2, Advanced IT Strategy Division
ITOCHU Techno-Solutions Corporation



Minsu Seo
Cloud Infrastructure Engineer

Rodrigo Chaves
Algorithm Developer

Jamie Friel
Compiler Team Manager

Atsushi Sugiura
Japan Country Manager

Owen Arnold
Lead Software Engineer

Hitoshi Kawahara
Associate Principal, Technology Research Department No. 2,
Advanced IT Strategy Division

Atsushi Sugiura
Oxford Quantum Circuits Limited
Japan Country Manager

Over 30 years of experience working for Japanese and overseas IT companies, with extensive leadership experience throughout his career.

Our Rapidly Evolving Society Values Diversity

——Since its founding in 2017, OQC has grown at blinding speed. The OQC Lucy, an 8-qubit[*1] quantum computer, debuted on Amazon Braket (US company Amazon's quantum computing service) in February 2022, and the same year raised 38 million pounds in Series A funding. Then in 2023 they commercially deployed their 32-qubit quantum computer "OQC Toshiko" installed at a colocation data center in Tokyo, and are currently raising a 100 million-US dollar round of funding. Could you tell us what kind of a company it is?

Sugiura: OQC was born in laboratories at the University of Oxford in 2017. OQC Lucy, announced at the end of 2021, was based on our company's core technology for quantum computing called Coaxmon[*2]. It became the first commercially-available quantum computer in Europe. Then in 2023, we made OQC Toshiko publicly available worldwide from a colocation data center in Japan, which brings us to where we are today.
Developments such as these are what we had envisioned from the beginning, but the speed of our evolution is accelerating each year. Our preparations for the next step are also currently on track. And as our first base for global deployment, we chose Japan. That was because the society in this country is highly mature, and also because the government and various technology communities here are seriously engaged in development for quantum technologies. I am looking forward to seeing what the future brings in Japan.

Owen: I think that our duty at OQC is to broadly provide the means to solve various social issues through quantum computing technology. To achieve that, it will be important for us to swiftly build environments where people from diverse industries can access quantum computers more easily and securely. We still need a bit more time to make that happen, but we have been doing what we can one step at a time, looking forward to when that day arrives. Having now made OQC Toshiko available to many different business users should progressively accelerate the advancement of this technology and help to hasten the arrival of the quantum computer age.

——I' ve heard that OQC Toshiko was named after pioneering Japanese female physicist Toshiko Yuasa.

Jamie: We name all of our computers after women from the field of science and engineering. For example, OQC Lucy was named after German physicist Lucy Mensing, who was one of the pioneers of quantum mechanics. Similarly, Toshiko Yuasa' s name was a natural choice for the computer that we aimed to deploy from Japan to the world. She worked for a long period of time with Mr. and Mrs. Joliot-Curie in Paris and produced outstanding achievements in the field of nuclear physics.

Sugiura: Our CEO is also a female quantum physics researcher. We are actively working to create environments where women can achieve even more success in the field of science and technology, which is why we name our computers after pioneering female scientists.

Rodrigo: OQC places heavy value on diversity. We have around 100 staff members from a total of 26 different countries. We aspire to be leaders in quantum computing,

and at the same time help to create a society where people from different backgrounds can live and work together.

The Significance of Multiple Coexisting Approaches

——Hardware for quantum computers is currently being developed through multiple varying approaches. For example, Amazon Braket can currently access three quantum computers. Two of those including OQC' s OQC Toshiko use the superconducting approach*3, while the other uses the trapped ion approach*4. How do you expect this situation of hardware being developed through different approaches will unfold going forward?

Owen: All of the quantum computers currently under development are what are referred to as devices of the NISQ (Noisy Intermediate-Scale Quantum Computer) era. They are "noisy" and "intermediate-scale," which in other words means that all of these devices are still works in progress. For that reason, they have their strong points and weaknesses, as well as technological issues to resolve. However, I think this current situation with hardware being developed through multiple approaches and having a diverse quantum computer ecosystem is really an excellent thing. It matches the history of how diversity was gained through the evolution process of transistors.
Development proceeding through different approaches with each of them advancing means that users have multiple options to choose from. That also shows how this industry is now truly growing. I am very much looking forward to seeing how each of these approaches evolves.

Jamie: To explain the differences between the approaches in simple terms, for example, the superconducting approach has the characteristic of being easy to scale up. In other words, the number of qubits is easy to increase. As a result, it has the major advantage of being easy to integrate with existing supercomputers and data center environments. On the other hand, the trapped ion approach might be hard to scale, but produces little noise and its qubits are high-quality. Therefore, it is good at outputting accurate calculation results. The points of qubits being either easy to scale or higher in quality is one of the differences between these two approaches. Also, the superconducting approach has the advantage of extremely fast gate speed, enabling it to perform calculations in far less time than approaches such as trapped ion.

Resolving Technological Issues in Parallel with Business Issues

——What were some of the challenges you faced in developing the OQC Lucy and OQC Toshiko?

Owen: One of the issues when building quantum computers with the superconducting approach is how to keep them cooled at low temperatures. We also struggled with that. We needed to maintain an ultra-low temperature only a few millikelvins above absolute zero, but conventionally it had been considered impossible to maintain such a low

Owen Arnold
Oxford Quantum Circuits Limited
Lead Software Engineer

In charge of the software that is essential to the operation of quantum computing systems.

*1 *2 *3 *4 Explanations of these terms are on page 11.

temperature for any longer than a few hours. After trying out various ideas, we were able to maintain that low temperature for gradually longer periods of time. OQC Lucy can now operate continuously for two years while maintaining ultra-low temperature.

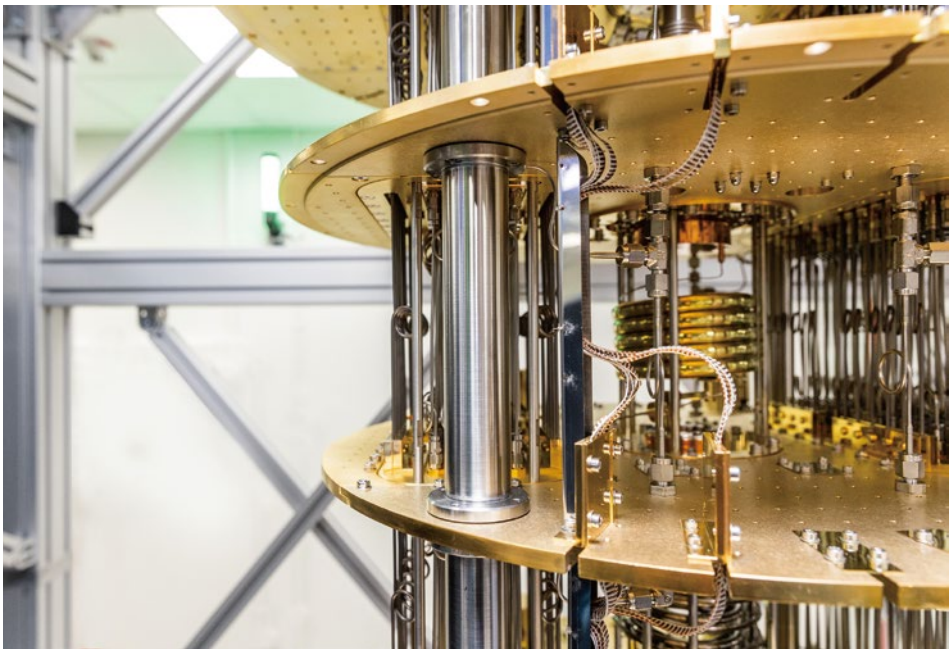
——What issues are you dealing with now? What are the technological issues, and what business-related issues are there?

Rodrigo: On the technological side, one is the hardware issue of how high we can raise the quality of the qubits. Increasing the stability of the qubits was a major issue when developing QOC Lucy, but with OQC Toshiko we are really focusing on how much we can improve their quality. Creating useful algorithms is also important, and that is what I am working on. In other words, that means developing specific methods for solving individual problems using quantum computers.

Jamie: In terms of software, out biggest issue might be how to make quantum computers into something that normal people can use. Even with the classical style of computers (= conventional computers) there are various difficulties in terms of programming, but the difficulty is even higher with quantum computers. We in the Compliance Team are trying to make them easier to use. Currently, quantum computer programming is in a very primitive state, like when classical computers were programmed using punched cards. Just as classical computers became drastically easier to use with the emergence of Windows, we are now working on developing software that can do the same thing for quantum computers.

Owen: From my perspective, I think the most important business-related issue is how to build an environment for people who really need quantum computers right now to be able to use this technology. In other words, this means supporting people who already have problems to solve which they would be able to solve with quantum computers, and showing that quantum computing technology can serve a practical purpose. That is another reason why it is important to overcome the technological issues that Rodrigo and Jamie mentioned. I think it is crucial to advance technologically and business-wise in parallel.

Jamie: With these issues in mind, I think it is incredibly fortunate for us to be able to work together with CTC going forward. In quantum computing, CTC seems to be a highly advanced organization with the technologies and knowledge needed in the short term, and also a long-term vision.



32-qubit quantum computer "OQC Toshiko" is installed at a colocation data center in Japan. It now provides services as a system that is easy to access for users not only in Japan but in other Asian countries as well.

Partnership Between Companies Fueling the Growth of Quantum Computer Usage

——Next I would like to ask about the partnership between OQC and CTC. First, please share an overview of CTC's initiatives in quantum computing.

Kawahara: We are working on quantum computing from two perspectives. One is to provide the environments for customers to use quantum computers. We launched CUVIC for Quantum as a service for that last year. We provide the support needed to use quantum computers in a wide range of fields, from combinatorial optimization to simulations, machine learning, and security. The other perspective is to go beyond providing environments and identify in an R&D-like format how quantum computing technology can be utilized in line with customers' individual issues, and make proposals accordingly. This is to say, we aim to develop new quantum algorithms and convert them into value for our customers.

——What was the background behind how the partnership between OQC and CTC got started?

Sugiura: We were looking for a formidable partner to help us approach potential customers when entering the Japanese market. Through that process, we met CTC and the partnership came together. CTC is a system integrator with a solid track record in many different industries in Japan, including telecom, manufacturing, finance, retail, and logistics. I am very glad to have established this partnership with them. More than anything, the reasons we needed the partnership with CTC were related to having installed OQC Toshiko at a colocation data center. Currently, all quantum computers other than ours are installed in one laboratory environment or another, but we thought that quantum computers would need to be installed at colocation data centers for companies to use them for business purposes. Specifically, to access a quantum computer in a laboratory, you either need to go through the public internet or build a private network incorporating that laboratory, which is not realistic in terms of cost or security. On the other hand, since our system is at a colocation data center, it can be securely

Jamie Friel
Oxford Quantum Circuits Limited
Compiler Team Manager

Building a revolutionary quantum compiler that can solve problems in OQC's hardware.

Rodrigo Chaves
Oxford Quantum Circuits Limited
Algorithm Developer

Linking the software team with the hardware team to develop the optimal quantum algorithms.

Hitoshi Kawahara

Associate Principal, Technology Research Department No. 2, Advanced IT Strategy Division
ITOCHU Techno-Solutions Corporation

Active in scientific fields for many years as an expert in numerical analysis, computational fluid dynamics, and high performance computing (HPC). He currently handles planning and development for CTC's quantum computer-related services.

Minsu Seo

Oxford Quantum Circuits Limited
Cloud Infrastructure Engineer

Builds cloud environments for quantum computer systems.

accessed from each company's existing digital infrastructure environment. And when companies build their access environments, I am positive that having CTC providing support is tremendously helpful both to us and our customers. For the foreseeable future, it will probably also be typical for quantum computers to operate in hybrid environments with existing computers. In those cases as well, I think it will be tremendously beneficial to have this partnership with CTC, which has expertise in a wide range of digital infrastructure from various types of computer environments to data centers.

Minsu: I also sense the importance of this partnership. That is because for quantum computing to grow, along with the evolution of the technology, I think it is also important to build the environments for all kinds of people to be able to use it correctly. From that standpoint, I also hope that partnerships like this one can be established all over the world. The growth of quantum computing is something that is probably only possible through the cooperation of numerous companies.

——What is the significance of this partnership with OQC from CTC's perspective?

Kawahara: First, that fact that OQC's machine (OQC Toshiko) is installed here in Japan makes this partnership feel extremely meaningful to us as well. Quantum computer machines are generally overseas and physically far from us, but even this machine currently installed in Japan has various constraints and we still cannot say that the barriers to its usage are low. In that regard, in addition to the machine being in Japan, we also have a relationship with OQC where we can confront the issues together while communicating closely with each other. Going forward, I hope we can build cooperative relationships in various areas and walk the long "path" of quantum computing's growth together.

How Can Quantum Computers Change the World?

——What role could quantum computers serve in the increasingly complex future era? We would like to conclude by hearing your outlook for the future.

Members of the OQC and CTC quantum computing teams had a friendly chat after the interview.

Owen: The fundamental principles of quantum computers are different from those of conventional computers. Classical computers often struggle to make accurate models of the real world, but quantum computers based on actual quantum behavior do not have that problem. They are able to accurately model the real world. For that reason, I think we might be able to solve complex problems that cannot be solved now if we use quantum computers. Furthermore, quantum computers have the advantage of consuming far less power than conventional supercomputers. In other words, this technology also has major implications toward building a decarbonized society. From that perspective as well, we believe that the development of quantum computers will help make the world a better place. We will continue doing what we can to make that happen, one step at a time.

Kawahara: The history of quantum computers has only just begun. It is still a work-in-progress technology. However, it is almost certain to become a technology that is essential in the future. We believe the important thing now to many of our customers is how to go about bridging that gap. It is critical for companies to make thorough preparations, which includes considering how this technology can be leveraged in each individual business. We want to provide services that can help customers in that regard. For that purpose also, I want to cooperate with OQC while taking a new step forward along with many others toward the dawning of a new era.

Quantum computer words to know

*1 **Qubit**
The smallest unit of information in quantum computers. Conventional computers assign values of either 1 or 0 to bits, but qubits have the characteristic of being able to achieve a "superposition" state that is simultaneously both 0 and 1.

*2 **Coaxmon**
OQC's patented technology which is the basis of its machines. This technology for the architecture of superconducting circuits—the core of superconducting approach quantum computers—created a simpler, more flexible architecture by making it 3D. As a result, this has made it possible to increase the number of qubits without sacrificing their quality.

*3 **Superconducting approach**
One of the approaches to quantum computers. It produces qubits via electric circuits that were put into a superconducting state by cooling them to ultra-low temperatures (electrical resistance equal to zero). Machines developed by IBM and Google use this approach, as does Japan's first domestically-produced quantum computer developed by RIKEN.

*4 **Trapped ion approach**
One of the approaches to quantum computers. It uses ions (+ and - charged atoms) trapped and manipulated by electric and magnetic fields as qubits. Research using this approach is also proceeding at multiple universities and research institutes in Japan including the Okinawa Institute of Science and Technology (OIST) and Osaka University.

Making Quantum Computing More Accessible

With ultra high-speed computation, quantum computers have the potential to solve complex problems that used to take time and were practically unsolvable. The companies, research institutes, and other institutions that use them will need new expertise to put them into practical use.
Here, we will introduce CTC initiatives and support services geared toward quantum computing.


Naoki Matsumoto (pictured at left)
Lead Specialist
Managed Services Development Department

Managed Services Planning and Promotion Division
Digital Services Group
ITOCHU Techno-Solutions Corporation

Hiroshi Suga (pictured at right)
Supervisor
Technology Research Department No. 2

Advanced Technology Division
ITOCHU Techno-Solutions Corporation

Heightened Expectations

Expectations are high for the tremendous social value that quantum computers could potentially generate, including for materials that advance decarbonization and the development of revolutionary new medicines. The Japanese government has set numerical targets for quantum technology of 10 million domestic users and 50 trillion yen of output in 2030. They have also announced a policy to actively engage in creating unicorns and startups that pioneer new future markets for quantum technology[*1].

Europe and North America had previously played leading roles in quantum technology development, but Japanese research institutes and companies are now accelerating their efforts.

CTC's Quantum Computer Initiatives

From researching the latest technology trends primarily with North American partner companies to joint research with domestic universities and specialized quantum computer startups and more, CTC has been active in R&D for quantum computer usage including application development since 2017.

In 2020 a specialized in-house organization was established, which launched full-scale efforts centered on three types of activities.

(1) Create new medium- to long-term industries by applying quantum technology and participating in various groups with the aims of learning the status of development at companies and professional networking

(2) Consider cases in which companies applied quantum technology to address real problems and pursue business development, press presentations, and academic conference presentations

(3) Share acquired knowledge at in-house study sessions and promote business development by promoting CTC's technological capabilities externally

For (1), CTC participated as a founding member in the Quantum STrategic industry Alliance for Revolution (Q-STAR) which was jointly established with 23 companies on September 1, 2021 (press release 1) with the goal of creating new industries in quantum-related fields. We also participate in corporate communities and industry-academia collaboration programs as we aim to advance quantum technology and help to create new industries.

For (2), we performed a simulation based on approximately 10,000 points in a 12-square kilometer area to optimize windmill positioning when building 20 windmills using NEC's quantum-inspired simulated annealing quantum computing service 'NEC Vector Annealing Service,' a form of quantum computing specialized in solutions for combinatorial optimization problems (press release 2). Since computation volume increases exponentially as positioning points and numbers of windmills increase, computation volume in the simulation grows vast when considering the effects of natural conditions such as the terrain and other factors between the windmills. In this case we developed an original computation model for quantum computing that took only 10 minutes to perform computations that took the previous simulation 10 hours. Since the calculation results produced were also on par with the proven existing results, the practical applicability of quantum computing for optimal positioning of windmills was confirmed.

For (3), we are sharing the latest trends in technology and CTC's initiatives with group employees through our internal communities and by holding regular

■Schematic diagram of CUVIC for Quantum

1. Quantum computer usage licenses

Amazon Braket　IBM Qiskit Runtime　Azure Quantum

2. Quantum usage assessment & algorithm verification service

Combinatorial optimization　Simulations　Machine learning

3. Quantum training service

Basics/beginner level　One-day hands-on quantum computer programming
Corporate training (3 months)　Corporate training (6 months)

4. Quantum platforms/managed services (planned release in April 2024 or later)

Integrated portal　Orchestrator　Library compilation　Monitoring & SRE

events. We have also established a special website that makes it possible to see verification devices used internally and related information at any time. We will deepen our employees' understanding of the technology by letting them get hands-on with quantum computers, and channel that into higher levels of expertise and skills.

Aside from that, we have been providing internships to university students since 2020 as a human resource development initiative. The employee-oriented learning programs we have arranged for university students are educational materials which are treated as university credits. We are focused on developing human resources who are prepared for the age in which quantum technologies are in practical use.

Services That Utilize Quantum Computing

In 2023 we began providing a service called CUVIC for Quantum (CUVIC-Q) which is geared toward the usage of quantum computing. This service is characterized by its ability to support practical application in a broad range of fields, from combinatorial optimization and simulations to machine learning, security and more, because it can simultaneously execute large volumes of computations using the principles of quantum mechanics.

Services Overview

- Quantum computer usage license

  We provide licenses to use the quantum computing environments offered by IBM, AWS, and Microsoft.

- Quantum usage assessment & algorithm verification service

  We are exploring the domains in which quantum technology can be used in assessment services. In algorithm verification services, we will develop environments and perform verifications and evaluations. Working together with quantum technology specialist partner companies, we will provide support to enable customers to utilize quantum technology in their actual work operations.

- Quantum training servic

  We provide technical training in three forms depending on the skills of the trainees. Working together with CTC Technology which offers operations and maintenance services and training for IT systems, we are also launching a succession of new courses.

To expand cloud-based quantum computing services, starting in April 2024 we plan to coordinate multiple quantum computers to provide quantum algorithms and software development kits (SDKs)*2 according to what is being computed. We will also provide platforms and managed services that make it possible to connect to various types of quantum computers.

Under the OneCUVIC brand name, CTC offers open hybrid cloud integrated platform services that help to reduce operations workload and bolster security for complex, sophisticated systems. CUVIC-Q which we began providing is also part of that. It adds cloud-based quantum computing services to managed services and managed security services to establish secure usage environments. We will strive to support our customers' businesses with this service.

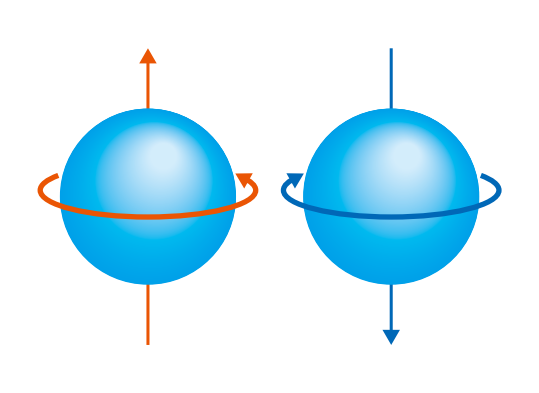
Press release 1
https://www.ctc-g.co.jp/company/release/20210901-01340.html

Press release 2
https://www.ctc-g.co.jp/company/release/20220616-01445.html

*1 [Source] "*Strategy of Quantum Future Industry Development,*"
Council for Science, Technology and Innovation, Cabinet Office, Government of Japan
https://www8.cao.go.jp/cstp/ryoshigijutsu/230414_mirai_gaiyo.pdf

*2 Tools that offer combinations of programs, APIs, and other necessities for application development.

IT Terminology



This issue's theme is...

[Quantum Computers]

Competition to build quantum computers with computation speeds exponentially faster than current computers is currently accelerating. In addition to IT giants IBM and Google, research institutes and startups in each country have also been announcing new technologies and machines one after another since the 2020s began. Multiple universities and research institutes in Japan have also been engaged in research, while new industry-academia collaboration companies seeking quantum computing commercialization are being launched. Are we not far from the day when quantum computing will be in widespread use? This article will explain our "current location" on that path.

Text by Yuki Kondo

Competition in Development is Accelerating Worldwide

In 2017 we also featured "Quantum Computers" in this column. It was thought at the time that quantum computers were decades away from becoming a reality. However, in the seven years since, the technology has come a lot farther than anticipated.

One of the indicators of the advancement of quantum computers is qubits, short for quantum bits (more details later). The Falcon processor unveiled in 2019 by the industry's leader IBM had 27 qubits. Since then, IBM has continued developing processors with at least double that number of qubits every year, unveiling the 1,121-qubit Condor at the end of 2023. They aim to surpass 4,000 qubits in 2025.

Multiple universities and research institutes in Japan have also been advancing their research. In March 2023, a 64-qubit machine developed by RIKEN, Fujitsu, NTT, and other joint research partners was unveiled as Japan's first quantum computer. In fiscal 2024, a new industry-academia collaboration company aiming to commercialize quantum computers will be launched by the Institute for Molecular Science in partnership with approximately 10 companies including Fujitsu, Hitachi, and NEC. UK startup Oxford Quantum Circuits Limited (OQC)[*1] also deployed its 32-qubit machine "OQC Toshiko" at a colocation data center within Tokyo and made it commercially available worldwide starting in November 2023.

Quantum computers were still considered something in the distant future in 2017, but now they are progressing steadily toward practical use. Will this technology soon be a part of our daily lives?

The Characteristics of "Superposition" and "Entanglement"

Quantum computers can be said to have computation speed 100 million times faster than the current supercomputers. In other words, they have the power to finish computations that currently take around three years and two months in only one second. How can quantum computers be that fast? The key lies in qubits.

Qubits are the smallest unit of information in quantum computers,

corresponding to bits in our conventional computers. The most significant characteristic of qubits is that they can achieve a mixed state called a "superposition" where they are both 1 and 0 at the same time, as opposed to conventional bits which must be either 0 or 1. To illustrate this property, if you have n qubits, you can calculate 2n states in parallel all at the same time. As a result, it becomes theoretically possible to attain speeds incomparable to conventional bits (which can only calculate 2n states one at a time).

Another important characteristic is that these computers can harness the concept of "quantum entanglement." This is when two or more qubits in a superposition state are correlated and affect one another. This concept makes it possible to manipulate qubits efficiently.

Both of these concepts are phenomena of quantum mechanics which arise in the actual world of atoms and molecules. The key to developing quantum computers lies in how to use these phenomena for the purpose of computing, or in other words, how to go about producing qubits. Machines using multiple varying approaches are currently under development which differ according to their method for accomplishing this.

Multiple Approaches Differ by Method Used to Produce Qubits

Currently, the most popular of the varying approaches is the "superconducting approach" used by companies including IBM. This approach produces qubits by putting electric circuits into a superconducting state (electrical resistance equal to zero), cooling them to ultra-low temperatures and assigning "0" and "1" information to factors such as the direction of electrical current flowing in the circuit. The trapped ion approach is an approach that is widely deployed in research. This approach is uses ions (+ and - charged atoms) trapped and manipulated by electric and magnetic fields as qubits. "0" and "1" are assigned according to the difference in the state of electrons within the ion. Other approaches include the photonic approach which produces qubits by assigning "0" and "1" according to the identified direction in which photons vibrate, and the cold atom approach which uses rubidium atoms cooled to almost absolute zero to produce qubits.

Various approaches are also being used in Japan. Among the aforementioned approaches, machines developed by institutions such as RIKEN use the superconducting approach, while new companies such as the Institute for Molecular Science use the cold atom approach. Research is also proceeding at the Okinawa Institute of Science and Technology (OIST) and Osaka University using the trapped ion approach, and at the University of Tokyo using the photonic approach, among others.

Each approach has its own strengths and weaknesses. For example, the superconducting approach makes it easy to increase the number of qubits, but is also prone to errors occurring in the qubits. On the other hand, the trapped ion approach has low errors, but cannot easily increase qubit numbers. It should be mentioned that since errors are prone to occur according to these properties, the level to which errors can be reduced has become a key point in development.

As development advances on multiple approaches, we still do not know if ultimately only one of these approaches will survive or if multiple approaches will coexist. However, the fact that various approaches of research and development are advancing simultaneously seems to speak volumes about the importance of developing quantum computers.

Will 2030 Be the Dawning of the Quantum Computer Era?

As development of quantum computers thus accelerates, it would seem that they could come into widespread use before long. However, that does not appear likely yet. The reason is that even though a computer can now have more than 1,000 qubits, we can also say that we need a million qubits for a computer to actually harness that potential. Also we might have the hardware, but it is also important to develop algorithms to utilize that hardware for solving individual problems as well as software that enables usage by people other than experts. These are still works in progress.

Google has set a goal of reaching 1 million qubits by 2029, but considering the communications coming from other research groups as well, it currently seems more likely that quantum computers for practical use will arrive around the year 2030.

How will development advance between now and then? Which approach will gain the upper hand? Over the next few years, our eyes will likely stay glued to trends in quantum computer development to find out.

*1 Special interview with Oxford Quantum Circuits Limited (OQC) and CTC in Special Feature page 4-11.

AKQA UKA: Elevating Customer Experience with Inspiration of Digital and Design

Inspired by market insights, ITOCHU Corporation drives clients' digital transformation (DX) forward by forming digital business alliances in partnership with companies boasting superior technology and functionality. One such entity, 'AKQA UKA,' was established as a joint venture between AKQA, ITOCHU Corporation, and CTC, focusing on advancing customer experience (CX) in clients' DX journey, thereby delivering new value.

Meeting the diverse needs of DX through the digital business alliance

The rapid evolution of digital technology is undeniable, with Japanese companies also embracing transformative measures through IT. However, Japan's position in the 'World Digital Competitiveness Ranking' fell by three spots to 32nd place last November, indicating a noticeable lag in DX compared to global peers.

DX is a pressing challenge for businesses, particularly in Japan, where there's an expanding need for DX to focus on transforming business models leveraging IT and digital capabilities. Hence, ITOCHU Corporation advocates for a 'Digital Business Alliance Strategy,' aiming to achieve customer DX through a market-centric approach and the enhancement and transformation of CX.

The Digital Business Alliance Strategy entails promoting capital and business alliances with multiple companies offering various functions such as consulting, data analysis, business design, marketing, CX, IT services, cloud, and BPO. It comprehensively addresses diverse DX needs by forming a 'digital value chain' among enterprises. Within this value chain, 'AKQA UKA' plays a pivotal role in enhancing CX.

AKQA UKA: Transforming Enterprise Value Through CX Innovation

Established in 2022 as a joint venture between AKQA and the ITOCHU Group, AKQA UKA's parent company, AKQA, was founded in the UK in 1995. Acquired by WPP* in 2012, it's renowned globally as a leading digital agency, guiding numerous successful CX transformations for world's prominent brands. ITOCHU Corporation entered into a business alliance with AKQA in 2020. Since then, it has collaborated with major domestic retailers, software providers, contact centers, etc., establishing AKQA UKA as a hub for AKQA's services to domestic enterprises.

While Japan's customer experience is globally acclaimed, much of it relies on interpersonal interactions, indicating that digital CX is still evolving. AKQA UKA, considering Japan's societal challenges like population decline and labor shortages, aims to enhance Japan Inc.'s brand strength in the

Case Study

Cases of Brand Value Delivered by AKQA

Scan these QR codes to see even more cases.

AKQA
https://www.akqa.com/work/

AKQA UKA
https://akqauka.com/

1 CX case: Nike
NIKE Training Club

Swiftly developed a fitness support app for at-home use. Helping to accelerate Nike's digital strategy by creating direct and continuous contact points with consumers.

Information Technology Business Department
ICT Division
ICT & Financial Business Company
ITOCHU Corporation

digital age while supporting the creation of new value beyond existing frameworks.
In an era where smartphones are ubiquitous and digital interfaces extend the touchpoints and time duration of customer interactions, CX becomes the lifeline determining a company's competitiveness. The key lies in thoroughly giving a tangible form to user perspective and seamlessly integrating advanced technology and design.
With a global network spanning over 50 countries and extensive CX expertise, AKQA, combined with ITOCHU Corporation's profound understanding of the Japanese market and its network of over 110,000 people across 62 countries, AKQA UKA and the digital business unit are collaborating to offer tailor-made solutions to business challenges.

Company Overview

AKQA uka

New perspectives reveal a world of opportunities.

Leveraging creative and design capabilities to transform customer experience.

Company name AKQA Uka
Established 2022
Headquarters 2-chome, Shibuya-ku, Tokyo

Areas of services: Branding & marketing, business consulting, customer insights design & data analysis, product & service development, interior & architecture design, system development & engineering

The company name "Uka" derives from the Japanese word uka which means to "grow wings" through metamorphosis. The name exemplifies our dedication to helping Japan's appealing brands spread their winds in the digital era.

2 CX case: H&M
H&M Loop

Developed an interactive area at H&M's main branch where old clothing brought in by consumers is recycled into new clothing in-store. H&M's effective promotion of this environmental effort earned the world's most prestigious advertising award, a Cannes Lions Grand Prix.

3 Branding case: BELLSYSTEM24
BELLSYSTEM24 Rebranding

Bell System24
Every voice matters.

BELLSYSTEM24 Holdings of the ITOCHU Corporation group launched its DX and rebranding efforts in 2020. Focused on inner branding to raise employee satisfaction in addition to revamping the logo and conceiving a new brand message.

* WPP plc: The world's largest advertising agency group, established in the UK in 1985.

‘Immersion Cooling’ Revolutionizes Data Centers for a Sustainable Future

Peh Swee Hong
CTO, CTC Global Pte. Ltd. (Singapore)

Joined CTC Global Singapore in 2013. With over 20 years of experience in the IT industry, he now leads the Technology & Innovations Department as CTO. Heading up CTC Global Singapore’s technology roadmap, he supports customers’ DX initiatives.

Data Centers Need an Urgent Solution

In today’s digital world of rapid business transformation, we play an extremely important role supporting demand for ever-increasing computing power and storage at data centers. Along with the rapid increase in data-intensive applications such as artificial intelligence, machine learning, and big data analysis, conventional air-cooled data centers are facing serious issues in terms of energy efficiency, cooling performance, and space utilization.

The global data center industry has thus been continuously in search of revolutionary solutions to deal with these issues. Immersion cooling, otherwise known as liquid submersion cooling, has emerged as a potentially revolutionary technology for the next generation of data centers in terms of efficiency, performance, and sustainability. Immersion cooling has been capturing attention even here in Singapore.

Excellent Energy Efficiency, Lower Cost and Failure Risk

One of the main advantages of immersion cooling is its excellent energy efficiency. This method immerses IT hardware such as servers and storage devices in dielectric fluid (electrically non-conductive fluid) with high thermal conductivity. Since dielectric fluid efficiently absorbs and dissipates heat generated by the hardware to maintain the optimal temperature for its operation, the energy-intensive air cooling systems and chillers that are typically used are no longer necessary. This can dramatically reduce energy consumption and operating costs while producing visible reductions in greenhouse gas emissions.

By maintaining a stable uniform operating temperature, it can also keep hardware failures to a minimum, extend the usage life of important components, and reduce the frequency of hardware replacements while reducing the environmental impact of electronic waste disposal from those replacements. This is also consistent with the principles of circular economy and sustainable resource management, thus contributing to sustainable approaches in data center management.

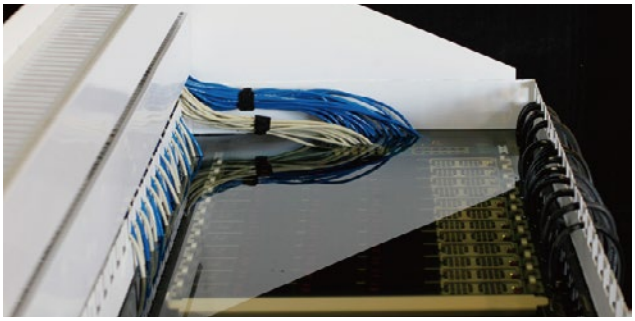
Since the dielectric fluid used in immersion cooling is non-toxic and non-flammable, this method also helps to make data center operations safer and more environmentally sustainable. It can help to minimize the impact of data center infrastructure on the ecosystem as a more eco-friendly alternative to the conventional air-cooled method which could become problematic in terms of global warming.

Contribution to Sustainable Digital Infrastructure

As companies are tending to place stronger emphasis on sustainability in their business strategies, usage of immersion cooling represents a concrete step toward aligning data center operations with environmental management and the Sustainable Development Goals. It enables companies to show a tangible commitment to contributing toward more sustainable digital infrastructure.

Immersion cooling has an enormous effect on the sustainability that can be achieved in next-generation data centers. This transformative approach can completely change the way data centers operate, offering better environmental responsibility, energy efficiency, and failure resistance. This method is an incredibly appealing solution that can satisfy the evolving needs of the new data-driven digital age at the forefront of innovation.

‘Immersion Cooling’ uses liquid to keep devices cool



News Pickup

Here is information on solutions and services
featured in CTC news releases.

GX x SDGs

Launched Leases with Carbon Credits as a GX Solution

We began providing Tokyo Century's leases with carbon credits as part of our lineup of GX solutions. This is a service to purchase carbon credits and offset the GHG emissions that arise with the use of IT devices when entering into leasing agreements for their usage. It can also be applied to IT devices that have already been purchased. Tokyo Century acts as the agent to handle the selection and purchase of carbon credits as well as the administrative work after use. CTC measures electric power usage, calculates GHG emissions, proposes replacement devices with higher energy-saving performance, and performs advance verifications of emissions reduction volumes.

Cloud x Operations & Maintenance

Developed the Pitwall™ Cloud Service that Standardizes Systems Operations & Improves their Efficiency

We developed and began providing a cloud service called Pitwall™ that makes information collection and coordination in system operations more efficient. It centralizes access to various types of management tools such as system monitoring, logging, and transaction tracing. The service also offers observability by visualizing the flows and patterns of responses to incidents when they occur. We will channel these capabilities to eliminate dependence on particular individuals by standardizing processes for system status verification and failure response, helping to improve the quality of responses at operations sites. Going forward, we also plan to release it in overseas markets.

AI x DX x Cloud

Developed an Investment Advisory Solution Leveraging Generative AI

Utilizing products from US company Aitomatic, Inc. which offers generative AI for specific fields such as the finance and manufacturing industries, we developed an AI investment advisory solution that proposes investment portfolios. It interactively handles investment-related questions and consultations and addresses investment portfolios in chat format including about risk and profitability while taking investment goals and constraints into consideration. We are also working on establishing services for portfolios including stocks, bonds, and other assets, to improve operational efficiency and advance DX in the finance industry.

AI x OSS x Global

Invested in the North America Partnership Program (NAPP)

In 2023 we initiated a collaboration between ITOCHU Techno-Solutions America, Inc. and the North America Partnership Program (NAPP) initiative to co-create business in North America with the aim of strengthening intellectual capital. We invested as a limited partner (LP) in OSS Capital, a US firm well versed in open source software, and a fund formed and operated by UK firm Dig Ventures Ltd. which has a robust network with European startups. We will also participate in management of startups with diversified investments through funds raised via venture capital.

AI x System Operations

CTC Technology to Provide Managed Services Utilizing AI

CTC Technology which handles operations and maintenance for IT systems began providing a managed service that leverages AI for system operations. Using machine learning to determine the system status from alerts, this service speeds up the process form fault isolation to first response. It deploys a solution from US company PagerDuty based on the AIOps concept of automating system operations with AI. We will contribute to speedy recovery from system failures, including automation throughout the first response by identifying important incidents and configuring program settings, as we strive to further improve the quality of managed services.

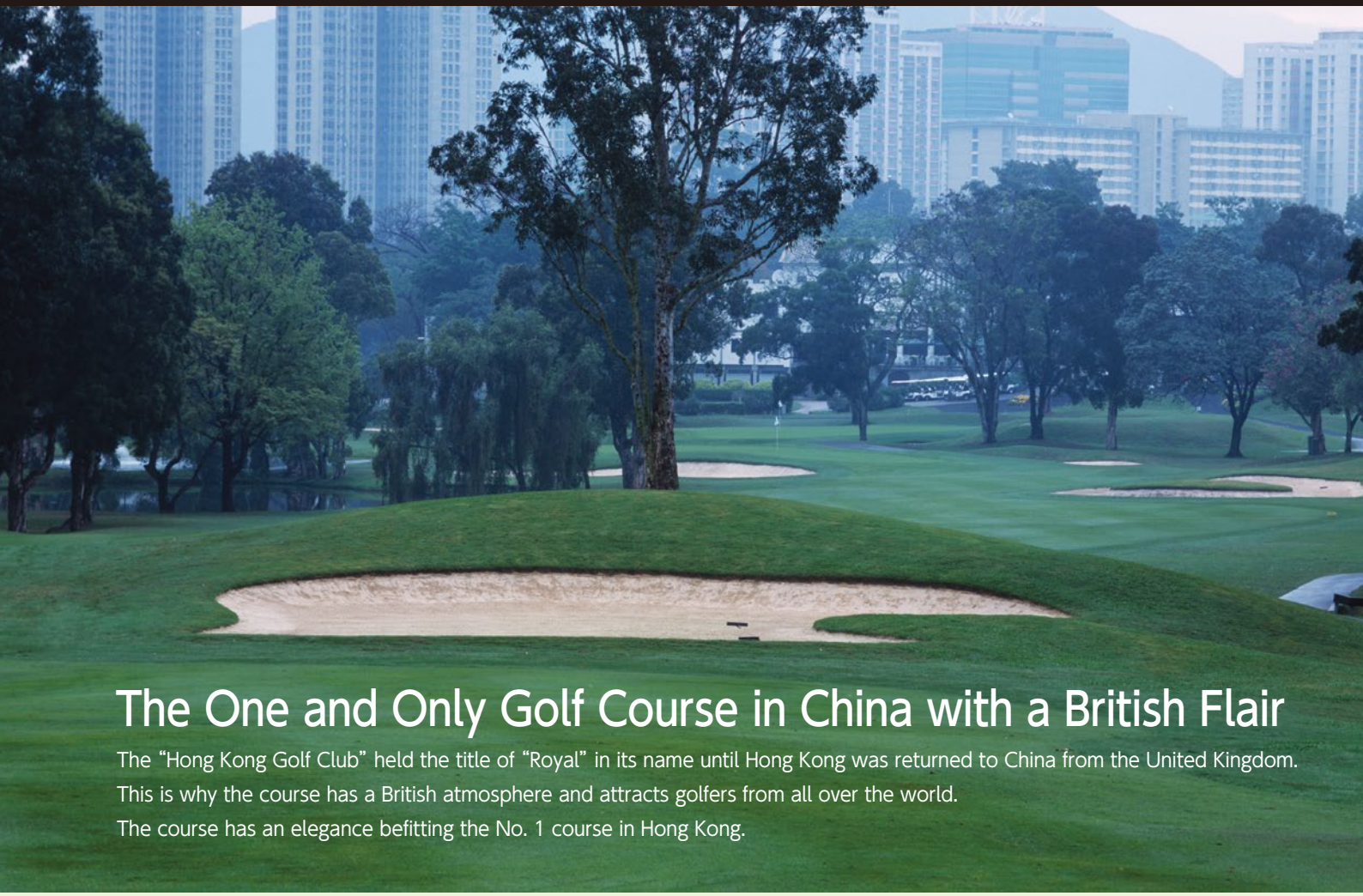
AI x Global

Launched Collaboration with Liquid AI to Develop Edge AI Solutions

We launched a collaboration with Massachusetts Institute of Technology (MIT) startup Liquid AI to develop edge AI solutions for applications including autonomous navigation of vehicles and drone control. This collaboration utilizes their AI, which is based on a method called Liquid Neural Network (LNN) that enables highly adaptive machine learning with minimal processing power. Making it possible to flexibly adapt to unknown environments and unexpected situations that deviate from previously learned data, we will advance development of edge AI solutions while verifying their utility in large-scale systems.

Please visit the link below for further details (Japanese only).

https://www.ctc-g.co.jp/company/



The One and Only Golf Course in China with a British Flair

The "Hong Kong Golf Club" held the title of "Royal" in its name until Hong Kong was returned to China from the United Kingdom. This is why the course has a British atmosphere and attracts golfers from all over the world. The course has an elegance befitting the No. 1 course in Hong Kong.

The Royal Hong Kong Golf Club was founded in 1889 as a 9-hole course in Happy Valley Initially, the area was shared with football, polo, and cricket stadiums, and golf was played by order. In 1891, the number of members exceeded 100 and the clubhouse was built. Women who had previously been prohibited from entering the golf course were allowed under certain conditions from 1896 onward. In 1898, a lease agreement was signed for land that provides swimming at Deep Water Bay, and a clubhouse was built. Members rode boats or ponies to the course, and caddies carried their clubs and picnic supplies, reminiscent of the leisure activities of the British who ruled Hong Kong.

54 Holes of Old, New, and Eden on 140 hectares of Land

In 1903, Happy Valley was acquired by the Golf Club on an exclusive basis and women were allowed to play on Sundays only. In 1911, North District officials negotiated with the government and local farmers to secure 18 holes of land in Fanling, and the Old Course was completed by the end of the year, followed by the New Course in 1931. In 1941, the lease of Deep Water Bay was terminated due to the course of war, and the house was converted to a military supply base. In 1947, Happy Valley was turned over to the government, effectively forcing the club into liquidation.

However, with the support of its members and local businesses, the restoration of Fanling began and the club was resurrected through a huge undertaking that lasted for 10 years. In 1970, the Eden Course was added and 54 holes were completed on 140 hectares of land, which continues to this present day. When Hong Kong was returned to China from the United Kingdom in 1997, the "Royal" title was dropped and the club became the Hong Kong Golf Club.

There are more than 3,000 organizations around the world that have been given the title of "Royal," and the late Queen Elizabeth of the United Kingdom and the Royal Family are invited to serve as patrons or heads of

The Hong Kong Golf Club, with a 130-year history since its foundation. A tranquil course with the atmosphere of the British colonial era. The gently undulating, well-separated holes welcome golfers.

Three Courses named Old, New, and Eden. There are guidebooks for first-time visitors.

the organizations. The conditions for earning the title are limited to "institutions with a high reputation, stable finances, and dedicated to national and charitable purposes." As an example, it can be said that it is similar to the criteria for selection as a supplier by the Imperial Household Agency in our country.

The World's Top Pros Have Competed and Honed Their Skills Here

Since 1959, the Hong Kong Open has been held here, making it the second oldest tournament to be held on the same course, after the Masters in the United States.

The tournament was also included in the Asian Circuit, and many of the players who later became major players participated in the event to test their skills. Among the names on the list are Australian-born, five-time British Open winner Peter Thomson who won three times (1960, 1965, 1967), Tom Watson (1992), and in recent years, Rory McIlroy (2011) and Justin Rose (2015). The most titles were won by Italy's Miguel Angel Jimenez with four championships (2004, 2007, 2012, 2013). There are also three Japanese champions. Teruo Sugihara (1969), Isao Katsumata (1970), and Seiichi Kanai (1986).

It also hosted the World Amateur Team Championship in 1984, which was the second of its kind held in Asia after Japan. I participated in this event as the leader of the delegation (International Committee member of the Japan Golf Association). We were able to win the team championship with captain Ginjiro Nakabe, and players Tetsuo Sakata (1st place individual), Kazuhiko Kato, Noriaki Kimura, and Kiyotaka Oie. The previous winners had been the golfing giants of Europe, the U.S., and Australia, but Japan's victory set the stage for a trend of "overthrowing the champion" among the subsequent winners.

The women's team did well to finish 4th, with captain Hisae Ozeki and players Yoshiko Ito, Michiko Hattori, and Yoshie Takahashi. I am grateful to the club for creating a turning point in the Japanese amateur golf community.

The course is English inland woodland style, and the fairways are carpet grass, a unique local wild grass. When standing on it, it has the fluffy feeling as if being in the rough, and when it rains, it has the vitality to grow 2 to 3 centimeters. It requires skill in irons.

Uncertain Future, with Pressure to Return the Land Due to Lack of Residential Land, but Voices for Its Continued Existence Is Equally Loud

Currently there are approximately 2,500 members. The breakdown is said to be 50% Hong Kong business tycoons, 40% from Britain, Australia and New Zealand, 7 to 8% from Japan, India, and South Korea, and only 1% from China. It is an exclusive membership with at least a 10-year waitlist to become a member, and corporate membership requires 100 millions of yen.

By the way, Hong Kong is currently experiencing a long and chronic housing shortage, and there is a growing public opinion to "convert golf courses to apartments." It is rumored that these circumstances may have been a factor for returning eight holes from the Old Course and the fact that it is not operating. However, the Hong Kong government has been reluctant to take action, possibly because it fears that losing the support of the Hong Kong business community will hinder its ability to maintain the regime.

There are competing arguments for preserving the golf club, saying that the loss of an urban golf course would destroy the remaining natural ecosystem and that "the loss of a course in a world-class international city that could host world-class tournaments would be a huge commercial loss for Hong Kong." It is very clear that once it is lost, it can never be brought back.

We would like to keep a close watch on how the situation will evolve.

Taizo Kawata

Chairman, Japanese Society of Golf Course Architects
President, T&K Incorporated

Born in 1944 in Tokyo. After studying at The Ohio State University, graduated in 1967 from Rikkyo University's Department of Law. His career includes the design of 23 golf courses and the remodeling of 29 golf courses. Has also served as a referee at major golf tournaments, including the British Open and the US Open.

Helping to Achieve Carbon Neutrality by Assisting Material Recycling

Material recycling takes the materials from products and reuses them as resources.
CTC has been using technology to solve previously inevitable recycling issues,
and has built and provided assistance for recycling supply chains that contribute toward achieving carbon neutrality.

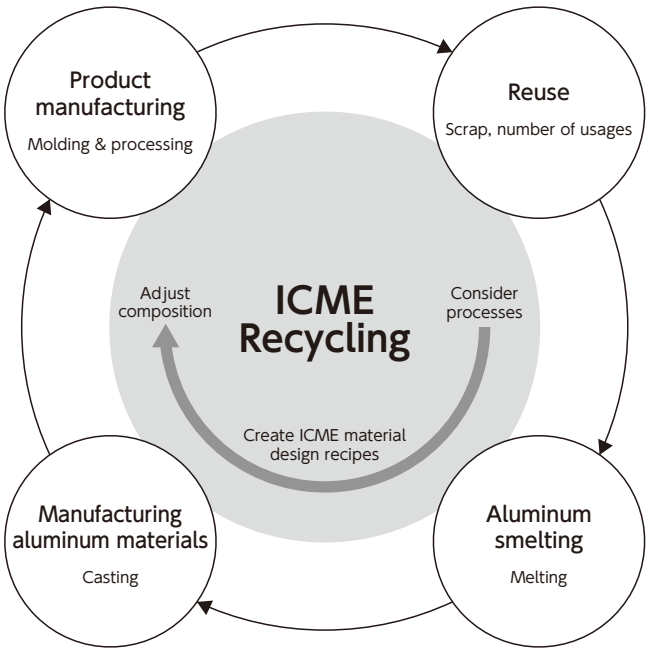
Recycling That Achieves Both CO_2 and Cost Reductions

Emissions from the industrial category and industrial processes are said to comprise 29.3% of all CO_2 emissions in Japan. Material recycling to reuse materials and resources what went into products is valued as an essential technology for achieving carbon recycling since it reduces CO_2 emissions and curbs consumption of natural resources.

However, material recycling also has many issues. One is that even a small amount of contamination by foreign substances in products being recycled can cause the quality to degrade. Since the technological and human labor costs to remove foreign substances add up, used materials at plants such as metals are typically changed out for simple products without being restored to their original strength or tolerance.

The carbon footprint ("CFP," a measurement representing all of the greenhouse gases emitted from the raw materials procurement for a product through its disposal and recycling, converted into CO_2) is also a difficult problem. From a company's perspective, reducing CO_2 emissions and working on CFP are requirements for sustainable growth. Therefore, it is critically important that they accurately understand their CO_2 emissions and lower the numerical values of their CFPs by recycling.

In order to solve these issues, CTC is proposing recycling supply chains based on integrated computational materials engineering (ICME). QuesTek* owns the US's leading technology in ICME. Using their system design charts that correlate with heat treatment and material properties to produce models, we measure composition, structure, and properties, and achieve the desired materials design through simulations.



Example of aluminum recycling via ICME

Major manufacturing clients are using this technology to build recycling supply chains that achieve carbon neutrality that costs less than new material production by recycling high-priced metals with their original level of performance. ICME technology can now even be used to track CFP which had been a difficult pursuit.

Using technology to discover answers to issues that vary by case, CTC is contributing to society in material recycling as well.

* QuesTek was founded by Dr. Greg Olson (MIT Professor), a pioneer in ICME technologies. CTC established QuesTek Japan jointly with QuesTek in 2020 and now provides advanced materials design.

Look RIGHT for further details (in Japanese only). ▶ Materials development & design solutions | https://x-simulation.jp/MaterialSolution

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Best Engine

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