Impact of AI and Quantum Computing in the smart machine age

Drs. Ing. PPM Huijbers

CTO Fujitsu Financial Services EMEIA

Your future digital "smart" organisation

1

The smart Machine Age:

all is becoming smart:

Hunting Society

Agrarian Society

Industry **1.0**

1780

Handcraftship

Animals

Information

Paper

FUJITSU

The Second Machine Age
Smart Machine Age:

Information Society

Smart Society

Industry **4.0**   Society **5.0**

TODAY

Smart Machines - Smart Robots
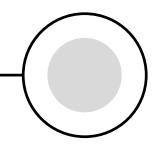
Smart Autonomous Vehicles

Intelligence

Digital

FUJITSU

Turing test

How Smart is AI?

automatic speech recognition + translation

Is she **real?**

Context recognition

sound samples

FUJITSU

Copyright © FUJITSU 2018

AI Components

Sensing & Recognition

Image recognition

Speech to text

Emotion recognition

Hand-written text recognition

Speech synthesis

Line-of-sight recognition

Video recognition

Behavior recognition

Knowledge Processing

Text analysis

Knowledge structuring

Classification

Speech comprehension

Knowledge searching

Discrimination

Decision & Support

Inference

Prediction

Dialog generation

Optimization

Question-answering

Matching

Smart Machines

Digital Data

Artificial Intelligence

Computer Power

Smart Do-ers

Autonomous Vehicles

Software Robots

Information based Robots

Smart Movers

Machines for „Do-Actions"

Smart Machines
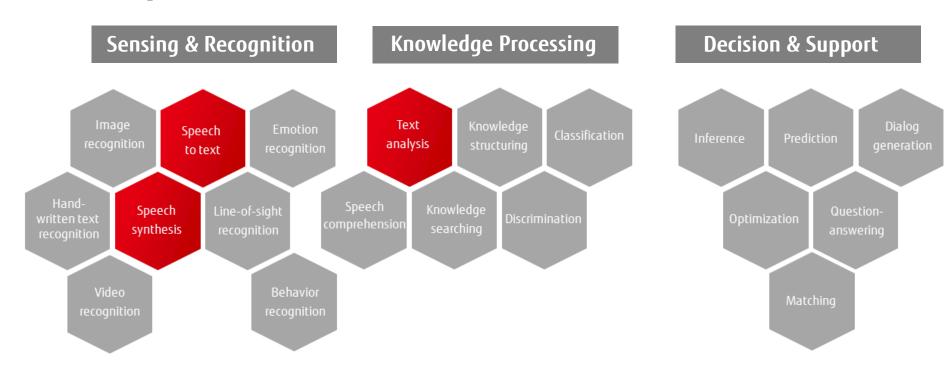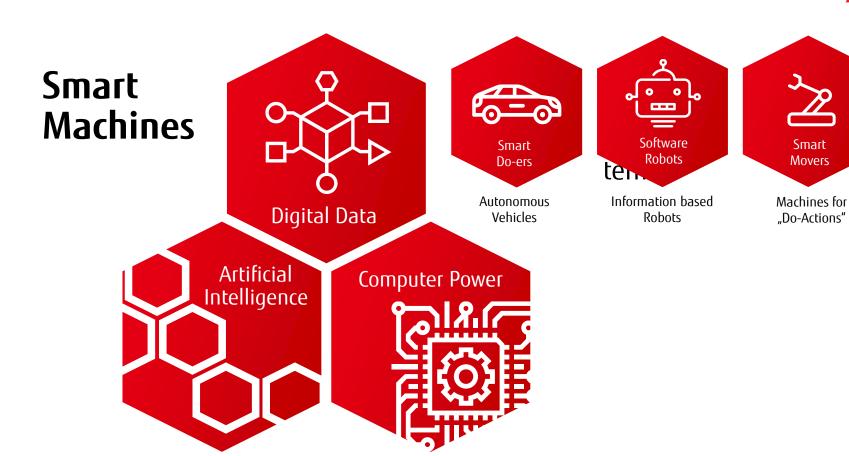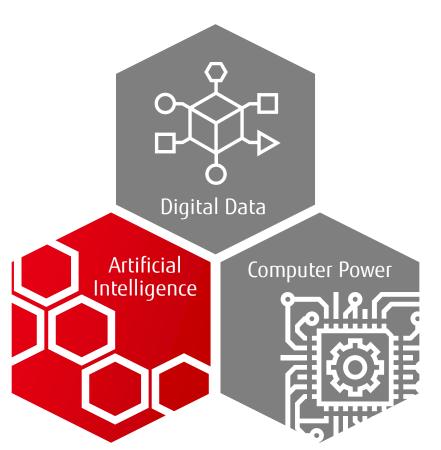

Digital Data

Artificial Intelligence

Computer Power

- 1672 – Gulliver's travel
- **1950 – Alan Turing proposes turing test**
- 1951- First AI programs
- 1969 – Stanford: Shakey the robot
- 1969 – First AI conference on Stanford
- 1997 – Chess champion
- 2002 - Roomba – Vacuum cleaner
- 2005 – ASIMO walk as human
- 2009 – First autonomous car
- 2011 – Jeopardy Winner
- 2014 – Smartphone assistants
- 2015- Go champion
- 2017 – Poker champion
- 2018 – Language processing outscores top humans at Stanford

FUJITSU

What can you do with AI Today?

- Predict
- Analyze
- Discover
- Detect
- Find

demand

performance, problem,...

insight, pattern,...

incident, opportunity

people, content,...

Looking for Specific (face recognition)

Optimization of Patrols

Detecting Unattended Objects

Detecting Specific Suspicious People
(looking for people by the color of the clothing, etc)

Customer Count at Shop

Congestion Detection

Illegal Parking

⚠ Attention
Games at nearby stadiums to end at the same time
Expect heavy traffic in the area till about 15:40

AUTO PLAY   0:00   4:00   10:00   16:00   00:01:28.910   × 12

🚆 Railway   Inbound Outbound

Average Occupancy Rate / Delay
North Line   121% / 13min
Circle Line   86% / 10min
South Line   64% / 7min
West Line   58% / -
Central Line   37% / -

🔴 EAST LINE   Train accident near South-bay Station
⚠ CITY LINE   15 minutes delay in North Line

Highway   Inbound Outbound
                                        92mile / -
                                        75mile / -
                                        64mile / -
                                        53mile / 15min
                                        21mile / 40min
                                        side Tunnel

TAXI

stion

677 riding

people

Average Occupancy Rate / Delay
                                        121% / 13min
                                        86% / 10min
                                        64% / 7min
                                        37% / -
                                        50% / -

24

50 °F   61 °F   69 °F   55 °F   51 °F
↗ 8 kt ↗ 10 kt ↖ 9 kt ← 14 kt ← 13 kt

⚠ After 1 hour   Torrential rain, thunderstorm

© OpenStreetMap contributors

☰ Transportataion   ☰ Security   ☰ Marketing

Smart Parking

Occupancy by Area

Trend

Occupancy by Slot

Image Capture

Shows Available Parking

Provides Information for Decision-making

Navigate Driver

AI
Market overview

MathWorks
TensorFlow
amazon DSSTNE
HITACHI
intel Saffron
Microsoft
H2O.ai
Google
ersatz labs
hp
FUJITSU AI Zinrai
FUJITSU
facebook BIG SUR
SONY
IBM
SIEMENS

Google TPU
IBM True North
FUJITSU DLU
NVIDIA Volta
Microsoft Project brainwave
intel Nervana

AI Optimized Hardware/CPU

AI Patents

Deep Learning Platforms

*Please see last slide for Trademark Legal Notice
/ Copyright © FUJITSU 2018

Artificial Intelligence Current – Finance Cases

Published by the Top10 Banks Worldwide

FUJITSU

Banks:
- Anti money laundering
- Real time automated trading
- Compliance effort (Regtech)
- Automated credit decisions / credit score
- Automate legal work
- Anti-fraud
- Virtual Customer interaction
- Smart Advisors
- Virtual Assistant and Self service
- Customer recommendations
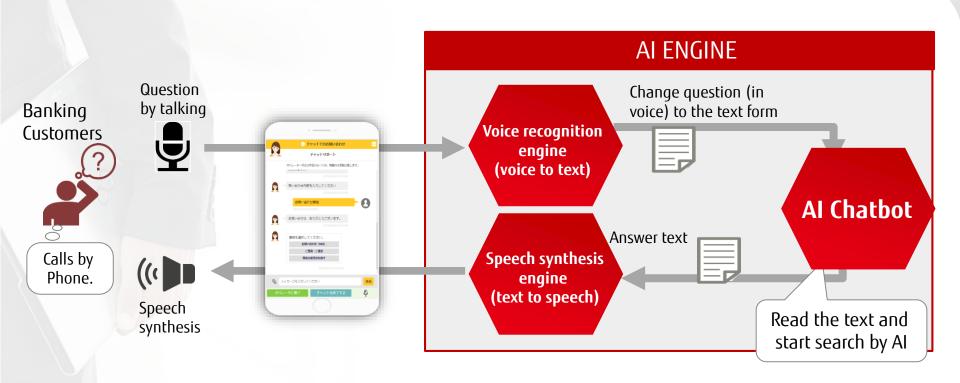
Insurers:
- Intelligent authentication
- Intelligent Quick Claim settlement
- Support investment decision
- Health Apps connected to Sensors
- Self Service Chatbot
- Calculate Insurance Payout
- Virtual customer interaction
- Blended human-AI Chatbot
- Chatbots for claims

Virtual agent – Chatbot with voice

"National AI Government policies and investments"

Canada
Canada saw government's role in AI research before many others, and made a $125 million commitment to AI research in March 2017.

US
The US has no central AI policy, but individual projects are funded by military and paramilitary departments like DARPA and IARPA. While little is being done on a national level, **AI industry and research is led by academia and private industry in the United States.**

Germany
Chancellor Angela Merkel spoke April 22 to the importance of competing with China in AI, due to China's aggressive goals of becoming the world's leading nation in the technology, but **the German government hasn't committed to investing.**

European Union
An April 25 report from the European Commission outlines a $24 billion (€20 billion) investment between 2018 and 2020. **The Commission expects to have a fully fleshed out plan for AI investment by the end of 2018.**

France
The French government will invest $1.8 billion (€1.5 billion) in AI research until 2022, president Emmanuel Macron announced in late March.

Russia
Vladimir Putin has made some grandiose comments on artificial intelligence, saying **that the leader in AI will "rule the world."** Many of Russia's AI demonstrations are military in nature, like AI-assisted fighter jets and automated artillery.
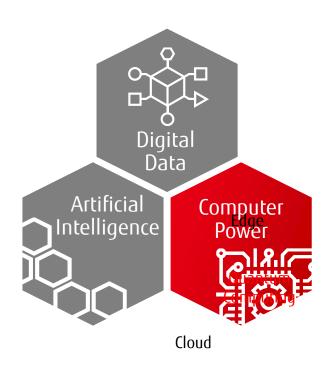
China
China is investing at least $7 billion through 2030, including $2 billion for a research park in Beijing. The Chinese government foresees a $150 billion AI industry by that time, **and has the most comprehensive national plan to become a leader in the technology.** Chinese startups also received 48% of all funding for AI investments.

FUJITSU

Smart Machines

FUJITSU

1968 Supercomputers are slower then your smartphone (Galaxy 7 or iPhone 7)

2018 for Quantum is as 1968 for traditional systems.

Why beyond classical computing

Easy problems versus difficult problems

The Navier-Stokes equations

It's surprisingly difficult to explain what happens when you stir cream into your morning coffee.

NP Problem

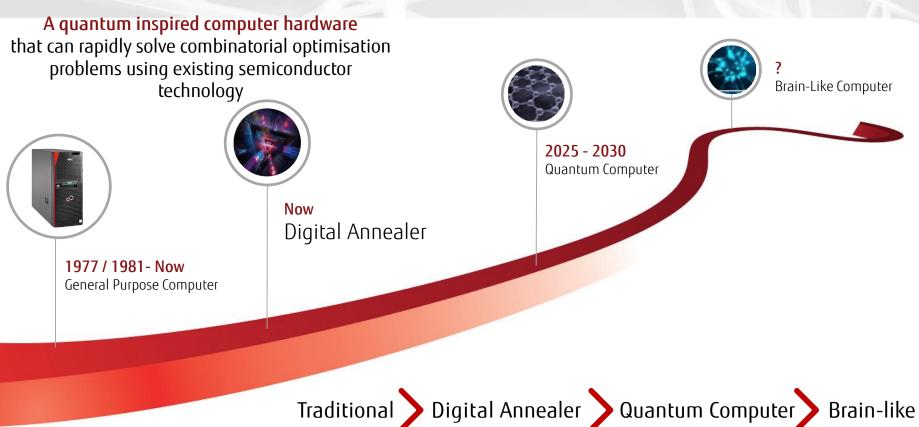Travelling salesmen problem.
Longest route or verify shortest route.

Cryptography

- Unbreakable Encryption?

Quantum inspired Computer Hardware

A quantum inspired computer hardware
that can rapidly solve combinatorial optimisation problems using existing semiconductor technology

?
Brain-Like Computer

2025 - 2030
Quantum Computer

Now
Digital Annealer

1977 / 1981- Now
General Purpose Computer

Traditional 〉 Digital Annealer 〉 Quantum Computer 〉 Brain-like

5 Minutes - Quantum Physics for CxO's

Rules powered by Nature

Superposition

Traditional

OPERATORS

0 or 1
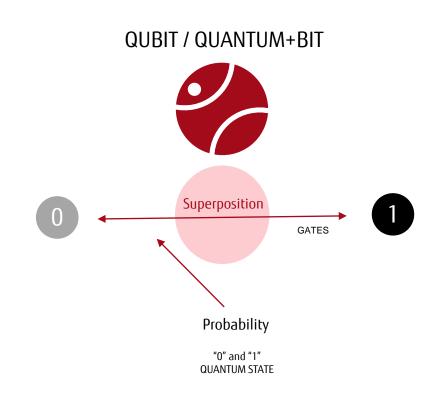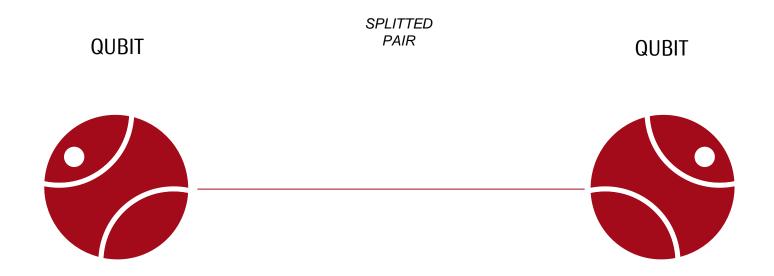
"0" or "1"
DIGITAL STATE

00 01 10 11

QUBIT / QUANTUM+BIT

0 ← Superposition → 1

GATES

Probability

"0" and "1"
QUANTUM STATE

Quantum Entanglement

SPLITTED PAIR

QUBIT

QUBIT
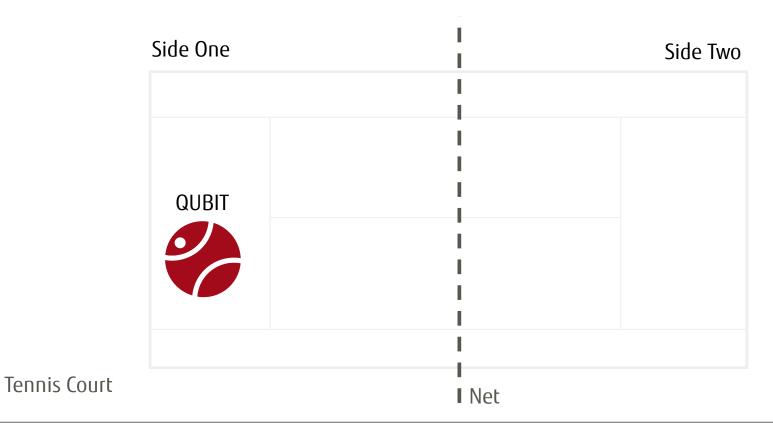
Spooking action communication at a distance – Direct interaction

Quantum Tunnelling
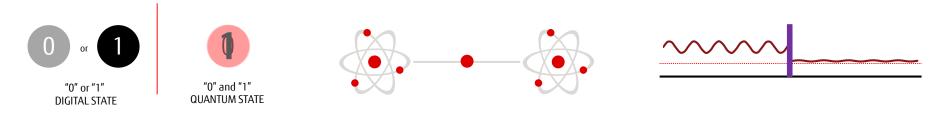
What is Quantum Computing?

Technology utilising quantum mechanics phenomena

0 or **1**

"0" or "1"
DIGITAL STATE

"0" and "1"
QUANTUM STATE

Superposition

Entanglement

Quantum tunnelling

Quantum Annealing
- Using quantum physics to identify the minimum energy points through mathematical algorithms
- Application: **Combinatory optimisation problems & sampling**
- Use Cases: Drug Discovery, Logistics, Portfolio Risk Management, Machine Learning, etc.

Quantum Gate
- Gate model Quantum Computers perform calculations by manipulating quantum evolution via application of gates — a basic quantum circuit operating on a number of qubits
- Use Cases: larger scale problems which includes cryptography, AI, search, other areas still being investigated
- Technically challenging to build as it is extremely hw specific
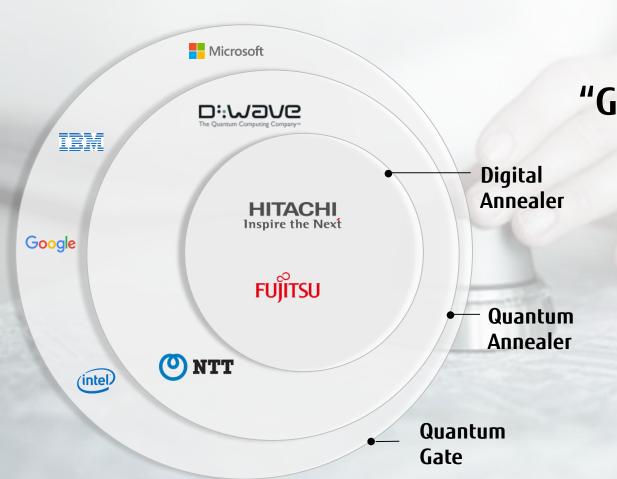
FUJITSU

Quantum
"Gates, Annealing and Inspired"

Market overview

Microsoft

D:Wave
The Quantum Computing Company™

IBM

HITACHI
Inspire the Next

Google

FUJITSU

intel

NTT

Digital Annealer
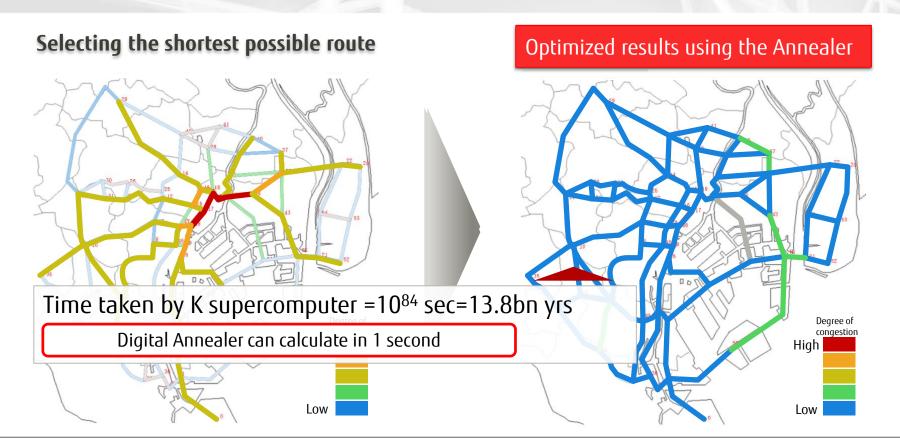
Quantum Annealer

Quantum Gate

What can all this power do?

It can solve problems exponentially and in parallel.

So what problems are exponentially complex?
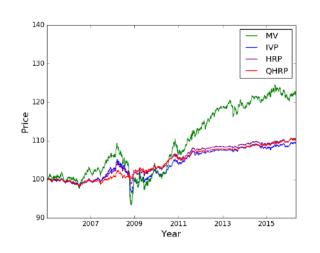
Finance | Traffic Route Optimization

Selecting the shortest possible route

Optimized results using the Annealer

Time taken by K supercomputer $=10^{84}$ sec$=13.8$bn yrs

Digital Annealer can calculate in 1 second

Degree of congestion

High

Low

Low

Finance | Portfolio Risk Optimization

optimal returns from safe investment portfolios

NatWest has begun testing with quantum computing power in order to solve some of the most complex, challenging, time consuming and expensive problems that the bank faces.

The experiment, which after successful testing is now being implemented by the bank, will see quantum-inspired computing power used to help portfolio managers decide on the right composition for the bank's £120bn high quality liquid assets (HQLAs) portfolio. HQLAs are assets such as cash and bonds that every UK bank must hold as a buffer in case it runs into financial trouble.

Using 'quantum-inspired' computing power, the bank's technology team have completed a highly complex calculation that needs to be undertaken regularly by the bank, at 300 times the speed of a traditional computer, whilst providing an even higher degree of accuracy.

https://www.rbs.com/rbs/news/2018/09/natwest-begins-testing-with-quantum-computing-power-to-help-solv.html

Digital Annealer Finance Use-Cases

Initial examples

Investment Portfolio optimization

Optimise ATM cash management

Non performing Loans

Optimal Trading

Credit scoring and classification

Bank customer segmentation

Reinsurance Optimization

Capital Management

Catastrophe Risk Modeling

Supercharged AI

FUJITSU

CO-CREATE, LEARN AND EXPERIMENT NOW

Up Next:
Use Cases and Quantum Annealing

Drs. Ing. PPM Huijbers

CTO Fujitsu Financial Services EMEIA

pascal.huijbers@ts.fujitsu.com

FUJITSU

Why look beyond classical computing?

FUJITSU

Solve a class of problems unsolvable today !

Disaster Recovery

Complex stochastic problem that combines:
- Resource allocation
- Warehouse routing
- Parallel fleet routing

Chemical & Material Science

Finding the best fitting out of a billion possible combinations:
- Drug design
- Molecular similarity

Logistics / Traffic route optimization

Continuous redistribution of position data for vehicles
- Identifying optimal route
- Time-critical optimization

Finance and Economic Policy

Dealing with 10^36 combinations or more
- Portfolio risk optimization
- Credit risk scoring
- ATM - Cash replenishment

Quantum Annealing

An Approach for combinatorial optimization : Annealing

■ Classical approach :
  Blocks are placed in sequence, starting over if it doesn't work. Repeated until a solution is found

■ Annealing :
  Blocks are placed randomly, then the entire system is "shaken", and the shaking is gradually reduced
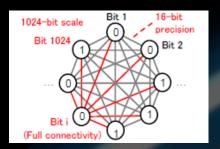
FUJITSU
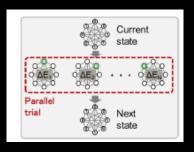
Quantum Inspired | Digital Annealing

The technology of solving combinatorical optimization problems effectively, overcoming the challenges of quantum annealing systems using 'quantum-inspired' digital circuit based architecture.
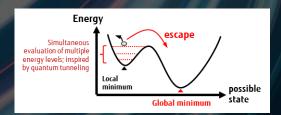
- **Inspired by quantum parallelism (superposition):** The DA evaluates all subsequent candidate states, arising from all 1024 possible bit flips, in parallel.

- **Inspired by quantum entanglement:** The full-connectivity of the DA enables quick interaction across the whole system state, reducing the overhead of mapping a real problem to hardware.

- **Inspired by quantum tunneling:** Unique hardware architecture simultaneously evaluates multiple energy levels, akin to quantum tunneling in quantum annealing, accelerating convergence.

Quantum Annealing vs Digital Annealing

FUJITSU

Commercially available Quantum Annealing computers requires a quantum state

Quantum-inspired technology available on digital circuit based technology

Escapes the local minimum energy state through the feature of Quantum tunneling ✅

Escapes the local minimum energy state by offset created with DA hardware architecture ✅

Maintaining quantum coherence requires expensive shielding and is nonetheless hard to sustain. ❌

Parallel evaluation of candidate states across 1024bit leads to multiplicative speed up & high precision ✅

Needs a cryogenic environment operating at a few milli-kelvin degrees thereby increasing complexity and costs ❌

Traditional digital bit-based energy efficient architecture working at room temperature that fits in a rack ✅

Limitation in solving large scale problems due to limited number of connections between qubits ❌

Architecture with full-connectivity with 16-bit precision and 26-bit biases, precision computation ✅

Digital Annealer Road Map

CY 2018

CY 2019

May 2018: DA Cloud Service introduced in Japan

2nd Generation

- Up to 8,192 bits
- Full interconnection
- Up to 64-bit precision
- 18.45 quintillion gradations

Next Generation

- Large-scale parallel-processing
- 1 million bit scale

1st Generation

- 1,024 bits
- Full interconnection
- 16-bit precision
- 65,536 gradations

On-Premises

DAU:
Digital Annealing Unit

Roadmap is subject to change without notice

Partnership with 1QBit

The world's top vendor providing Quantum computing software on WebREST API

DA uses standard Quantum annealing API (QUBO), hence eases transition without having to tweak customer's core application
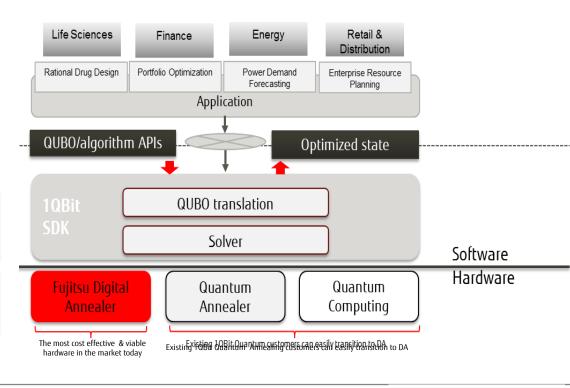
Middleware
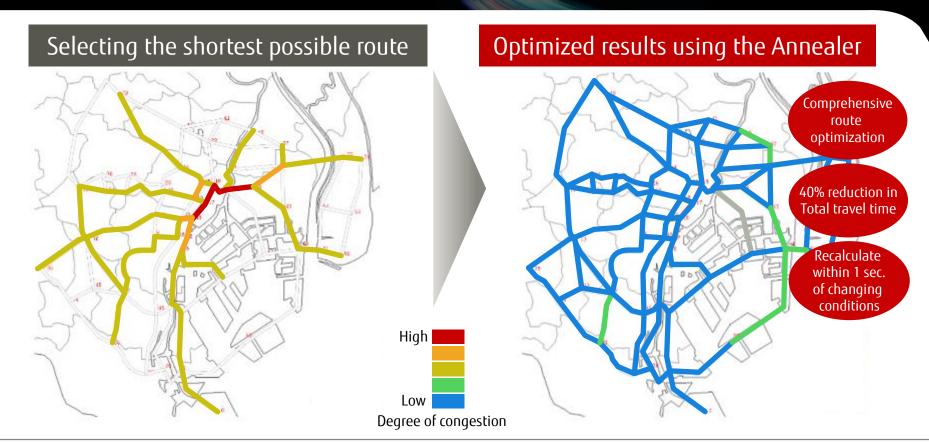Mathematical formulae and algorithms for computation

Hardware
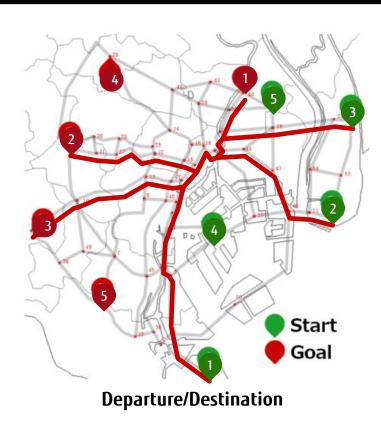Delivering processing that can solve problems with high speed and high precision

Life Sciences	Finance	Energy	Retail & Distribution
Rational Drug Design	Portfolio Optimization	Power Demand Forecasting	Enterprise Resource Planning

Application

QUBO/algorithm APIs   Optimized state

1QBit SDK
QUBO translation
Solver

Software
Hardware

Fujitsu Digital Annealer   Quantum Annealer   Quantum Computing

The most cost effective & viable hardware in the market today

Existing 1QBit Quantum customers can easily transition to DA
Existing Fujitsu Quantum Annealing customers can easily transition to DA

Use case | Comprehensive route optimization

Selecting the shortest possible route

Optimized results using the Annealer

Comprehensive route optimization

40% reduction in Total travel time

Recalculate within 1 sec. of changing conditions

High

Low

Degree of congestion

Use case | Traffic Route Optimization

Start
Goal

Departure/Destination

Comprehensive Route optimization to ensure no overlapped routes and ease traffic congestion

No. of combinations of route candidates for 5 different pair of start and destination goal = 10^{100}

Time taken by K supercomputer = 10^{84} sec = 13.8bn yrs
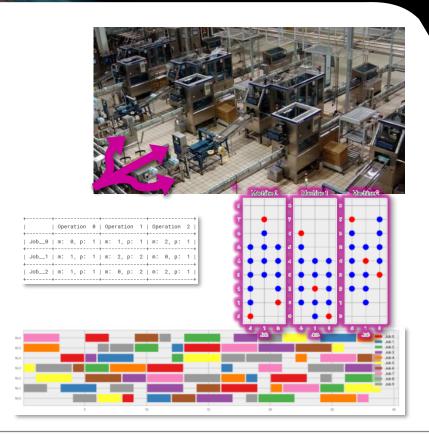
Digital Annealer can calculate in 1 second

- Production jobs are sequences of operations on machines

- Scheduling due to conditions (operation order, duration, ...)

- Minimize overall production time

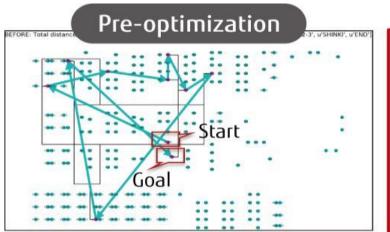- Fast replanning in dynamic factory

- Solvable by annealing
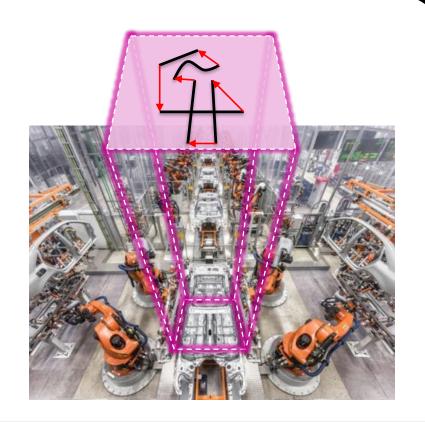
■ Welding robots "visit" seam location

■ Seam can be welded in 2 directions

■ Find best welding directions and optimal roundtrip between endpoints

■ $2^{n-1}(n-1)!$ possibilities

■ Solvable by annealing

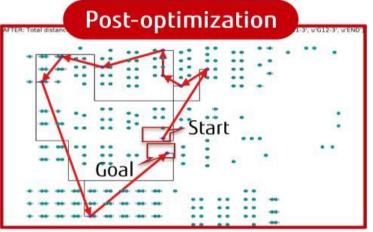- Optimized Placement of In-Stock Parts in Factories and Distribution Warehouses

Work route: 193.5 m in total → 30% reduction → Work route: 138.3 m in total

Additional optimization of parts placement and shelf layout reduced traveling distance by 45% per month.
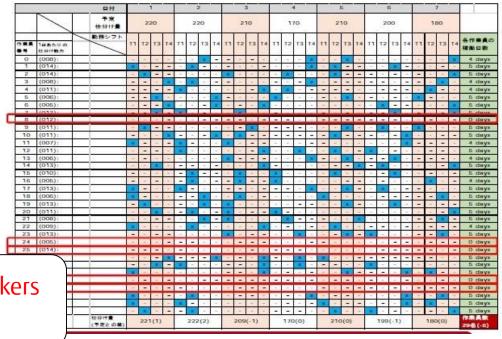
Use case | Workforce optimization

Workforce planning in Factories and Distribution Warehouse

Condition example
- Fulfil each shift work request
- Minimize number of workforce
- Maximum workload per day: 1 shift
- No working across days
- 2 Days off per week

7days, 4 shift/day → 34 workers

DA optimized work shift plan with 29 workers and secured 5 workers for other tasks
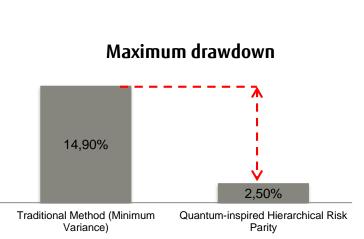
Portfolio Management use cases
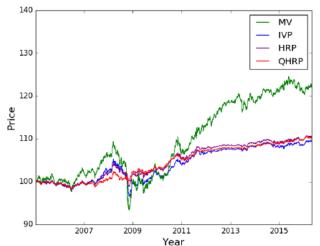
Use case | Portfolio Risk Optimization

Minimize portfolio risk using Quantum-Hierarchial risk parity potentially avoiding 2008 financial crisis

Use case | Portfolio Risk Optimization

Financial services benefit from Digital annealing by allocating capital optimally across a pool of assets by choosing from a lot of interconnected data points and dependencies.

Method	Maximum Drawdown (%)	Sharpe Ratio
MV	14.9 ± 2.7	0.51 ± 0.16
IVP	8.3 ± 0.4	0.54 ± 0.03
HRP	5.0 ± 0.6	0.70 ± 0.06
QHRP	2.5 ± 0.9	0.82 ± 0.13

The average price of portfolios provided by
- **MV:** minimum-variance optimization
- **IVP:** inverse-variance parity
- **HRP:** hierarchical risk parity
- **QHRP:** quantum-inspired versions of HRP
as a function of time on the
Commodity Trading Advisor (CTA) index.

What it means:
Sharpe Ratio is a fund's risk adjusted returns. i.e the fund's return relative to the risk taken.

Maximum Drawdown% is an indicator of downside risk over a specified time period.

Vertical & Use cases
Finance
- Portfolio risk optimization
- Portfolio Governance
- Portfolio Modeling & Simulation
- Asset Valuation

QHRP based portfolio selection provides the highest sharpe ratio and lowest drawdown.

Services & Solution

Our Human Centric Experience Design approach enables you to...

FUJITSU

1 **Understand** your business challenge within the context of your strategy

2 **Look** at the issues through different lenses

3 **Combine** business and technology expertise to develop rapid outline concepts

4 **Develop** joint working plan for immediate experimentation

Engagement Model

FUJITSU

4 ingredients

People
Experts from business and technology

Purpose
Focus on a business imperative

Outcome
Deliver value by implementing at scale

Design
Develop solutions quickly for experimentation

4 steps

1 Consulting
address an imperative through collaborative engagement across the business

2 Co-Creation
coming up with ideas to resolve a challenge

3 Implementation
exploring a range of potential opportunities

4 Concept development
Ten days support by digital annealer expert and adequate annealing performance from Fujitsu cloud service at fixed price.

Service Overview

FUJITSU

❑ Cloud Service and Technical Service launched in 2018

➤ Realize high speed processing for combinatorial optimization problems

   "FUJITSU Quantum-inspired Computing Digital Annealer"

➤ To support customers' Digital Annealer utilization

   "Digital Annealer Technical Service"

Cloud Service

Technical Service
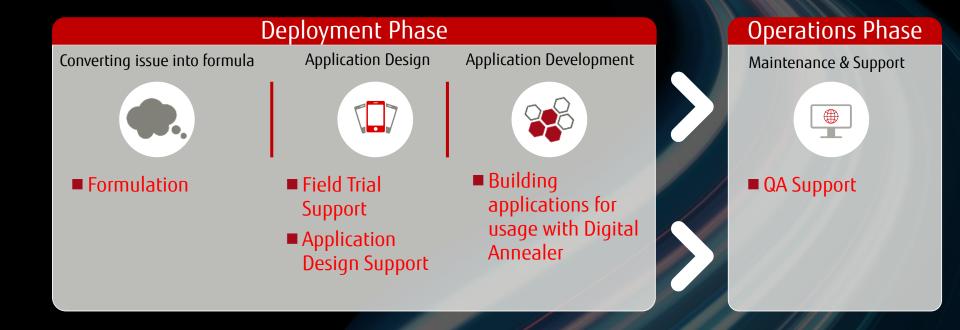
Various combinatorial optimization problems in actual

On-Premise (Planned)

Digital Annealer Technical Service

FUJITSU

"Hand-in-Hand" technical service supporting customer to resolve challenges
—Technical experts with advanced mathematics knowledge and data analysis capability

Deployment Phase

Converting issue into formula	Application Design	Application Development

- Formulation
- Field Trial Support
- Application Design Support
- Building applications for usage with Digital Annealer

Operations Phase

Maintenance & Support

- QA Support