Orchestrating a brighter world

NEC

NEC's Research and Development

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Executive Summary

*1 At the international benchmark tests by the U.S. National Institute of Standards and Technology (NIST). Results shown from the Face Recognition Vendor Test by NIST do not constitute endorsement of any particular product by the U.S. Government.
*2 Covers NeurIPS, ICML,KDD,ECML-PKDD and ICDM. NEC estimates (2000-2017).

Constantly create No.1 technologies that support NEC's businesses

- Laboratories have established competitive edge that contributes to the company's business in focus and other businesses

  e.g.) **Face recognition technology which marked the world's No.1 evaluation for four consecutive times**[*1] and AI technologies which ranked **5th in the world**[*2] in terms of the number of papers that were adopted at top-quality international academic conferences

  ⇨ **Further strengthen AI technologies** and focus on **social acceptance, expansion of human capacity and mutual cooperation between AI and human**

Continuously acquire global top researchers

- The source of technological advantage is human resources. Provided more than enough opportunities in activities and compensations to acquire top researchers
- Research Fellow positions without limits on incentive founded in 2015. Market-level compensation being offered at NEC Laboratories America

  ⇨ **Introduced "Selective Compensation Program for Professional Researchers" without limits on compensations for non-managerial researchers**

A new strategy, "Ecosystem-oriented R&D with NEC's cutting-edge technologies"

- Shift to a new form of R&D operations, anticipating new relationships between researchers and the company to address a drastic market change

  ⇨ **Inbound & Outbound fusion-type open innovation that involves external parties**

  ⇨ **Enhance speed of R&D** to prepare for a spurt in the next era

Mission of NEC's R&D

Constantly create No.1 technologies that lead to advantages in existing and future businesses

- **Create No.1 technologies unparalleled by others and solid solutions comprising those technologies as a core**
- **Forecast disruptive technologies and develop technologies in preparation for social changes in the future (=business opportunities)**

R&D 7 bases in the world 900 researchers

Core Technologies

Central Research Labs (4 research div.)	Develop core technologies for AI and ICT platforms
NEC Labs America	Focus on research into cutting-edge AI technologies using its favorable location as a mecca for high-tech
NEC Labs Europe	
NEC Labs China	R&D and enhancement of AI and security through social implementation in the EU

Solutions

NEC Labs India	Create solutions for social issues jointly with customers in real business locations in the emerging country
Israel Research Center	Promptly create solutions by combining external advanced technologies and NEC's ones in the world's leading country of startups
NEC Labs Singapore	

Business Innovation Unit → Create new businesses with technological seeds as a core

Digital Business Platform Unit → Prepare a company-wide common technological package

Cross-Industry Unit → Differentiate various businesses

Business Units

(For Reference) R&D's Contribution to Entire NEC

Marked **the World's No. 1 for 4 consecutive times*** in face recognition of still images and videos under various environments; applying for the 5th No. 1 evaluation.
Adopted as a new boarding procedure, One ID, at Narita Airport

*At the international benchmark tests by NIST. Results shown from the Face Recognition Vendor Test by NIST do not constitute endorsement of any particular product by the U.S. Government.

AI automatically calculates prediction models. A non-professional can achieve in a day what it takes several months for a professional to achieve.*
Established dotData Inc., which has obtained more than 20 client companies

* A result from joint verification with a customer

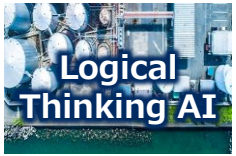
Analysis of medical treatment information **detects 71% of signs of patients' agitation 40 minutes before and finds out 87% of high-risk patients for aspiration pneumonia**. **Support hospital management reform at Kitahara Neurosurgical Institute (KNI)**

Recognize multiple objects placed in a disorderly manner, such as vegetables in indefinite shapes and similar packages, **at the same time**. **Realize object recognition PoS systems with an error ratio of 0.1% or less for more than 10,000 goods, adopted by an operating company of Seven-Eleven convenience stores in Taiwan**

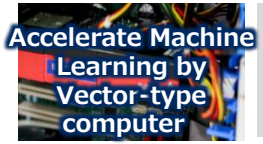
Predict neoantigens unique to each patient by modeling experimental data and biochemical knowledge as a knowledge graph*. **Started clinical trials for individualized neoantigen vaccines jointly with Transgene SA**

* A structure comprising points and lines that connect them

Outcome of NEC–RIKEN-AIST AI Cooperative Research Lab.
Efficiently discover very rare faults with 100 millionth probability as AI repeats simulations while it learns.
Support design of equipment by simulations



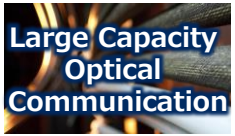
Outcome of NEC–AIST AI Cooperative Research Lab.
Derive optimal solutions and their grounds speedily by narrowing down candidate solutions with logical reasoning and reinforcing learning using simulations.
Support optimal operations at large-scale plants



Overwhelmingly accelerate a statistical mathematics-type machine learning used for recommendations and other functions, by way of a vector-type computer.
Enable easy and real-time AI application by complying with the spreading Spark Framework

Realize **a tool that allows anyone to be able to develop systems using secure computing by automatic generation of necessary codes. Support the development of a medical data distribution platform which needs safe use of data**

High-speed tampering detection which **can be used for IoT equipment** with insufficient performance. Detect **tampering** of IoT equipment by a cyber attack at a factory **at an early stage**. Contribute to preventing damages from spreading to the destruction of production lines



Nonlinear compensation using AI **for the first time in the world** and demonstrate **the world's best performance** in optical submarine cables.
Outcome of an advanced joint study with Google

Competitiveness of NEC's Research in Academia

Good presence at top-quality academic conferences tells strength in technological advantages

AI

- **Ranked 5th in terms of # of accepted papers at top-quality international academic conferences on machine learning*1 (since 2000, company survey)**
- **Many papers accepted at top conferences also in other AI fields*2**

*1 NeurIPS, ICML, KDD, ECML-PKDD and ICDM
*2 AI in general: IJCAI, AAAI, image recognition-related: ICCV, ECCV, CVPR, etc.

Security

- **Many papers accepted at top-quality academic conferences on cyber security, incl. ACM CCS, Eurocrypt and IEEE S&P, etc.**

Network

- **Many papers accepted at top-quality academic conferences on optical communication (OFC/ECOC) for over 30 consecutive years**

Patent

- **Ranked 5th in the world in terms of # of AI-related patent applications (2019)**

Source: WIPO / WIPO Technology Trends 2019 - Artificial Intelligence
https://www.wipo.int/edocs/pubdocs/en/wipo_pub_1055.pdf

No. of Accepted Papers at Top-quality Int'l Conferences (machine learning)

1	Microsoft	680
2	IBM	659
3	Google	393
4	Yahoo	299
5	**NEC**	**154**
6	DeepMind	125
7	Facebook	68
8	AT&T	65
9	NTT	62
10	Baidu	56

Company survey (2000-2017)

Contribution of No.1 Technologies to Businesses: Face Recognition Technology

World's No.1 face recognition technology contributes to various businesses from monitoring to customer service

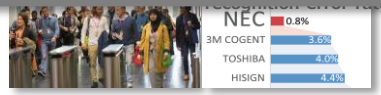
High Technological Competence

Win the world's No.1 evaluation for 4 consecutive times

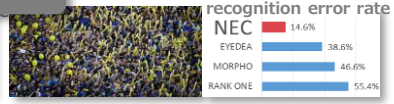
Results of NIST accuracy benchmark tests

- **No.1 accuracy in any environment**

Whether at gates or audience seats



Good environment: Test at a passenger gate

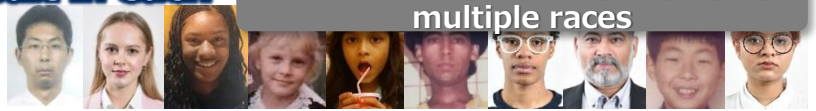


Bad environment: Test at a stadium

- **High accuracy irrespective of race, gender, age, etc.**

No.1 result in each item

Posture change, change by aging, multiple races



Reliability for Security

"NEC Group AI and Human Rights Principles" enacted in April 2019

Contribution to Businesses

Creation of social value with face recognition technology

- **Walkthrough entry by face recognition**
- **Empty-handed payment**

Seven-Eleven Japan

- **Accurate identification and speedy boarding**

Narita International Airport

One ID, new boarding procedure adopted to Narita International Airport

Case of Social Solutions with Technological Core: Digital Hospitals

AI researchers enter business locations and jointly establish on-spot reform toward sustainable medical treatment

Enter real medical treatment sites and find issues to be solved

Solutions derived from medical treatment sites

Data from medical treatment sites × AI

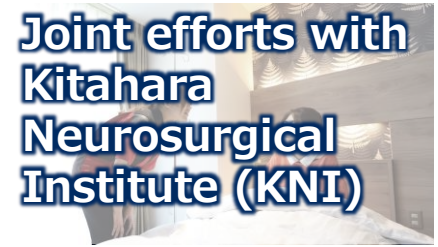
Value to Hospitals

- Reduce workload at hospitals
- Shorten hospitalized periods
- Improve QoL

Value to Patients

Case

Joint efforts with Kitahara Neurosurgical Institute (KNI)



Electronic medical records × Analysis with explanation to which those engaging in medical treatment understand → Find 87% of high-risk patients for aspiration pneumonia at early hospitalization stages

Vital data × Real-time analysis of a large quantity of data → Detect 71% of signs of patients' agitation 40 minutes before

Direction of NEC's R&D

Design social foundation with AI to realize abundant society for all people

Secure AI's safety and fairness to enhance social acceptance of AI

Face Recognition

Strengthen fairness and resistance to the environment

Multimodal Biometrics

Face Iris Voice • • •

Collectively recognize many faces in a wide area

Understand inside of people and things

Reliable AI

Extend human ability with AI which people can understand and cooperate with

Develop earlier than any others in the world

Explainability for Analysts

Heterogeneous mixture learning

Predictive Analytics

Explainability and Transparency Accepted by Anyone

AI that gives a new insight

Collaboration among AI systems

Provide AI foundation that is easily introduced and make AI spread all over human society

Cloud-based Use

Realize processing on Edge with low energy consumption, compact AI systems

Integrate distributed AI systems

Assure security from cloud to IoT

Improve communication performance by AI

Safety

Security

Efficiency

Equality

Realize society "abundant for all people"

High-level Researchers Who Support Creation of No.1 Technologies

Attracting many distinguished researchers. Both people and laboratories appeal to researchers and foster them

Internationally Acclaimed NEC Researchers

Hitoshi Imaoka
World's No.1 face recognition technology

Youngest-ever NEC Fellow

Kazue Sako
President of the Japan Society for Industrial and Applied Mathematics (-June)

Ting Wang
Verification of the world's Fastest AI optical communication

Ghassan Karame
High-speed blockchain

Mathias Niepert
Graph-based relational learning

Hans Peter Graf
Development of machine learning PF "Torch"

Manmohan Chandraker
Computer vision

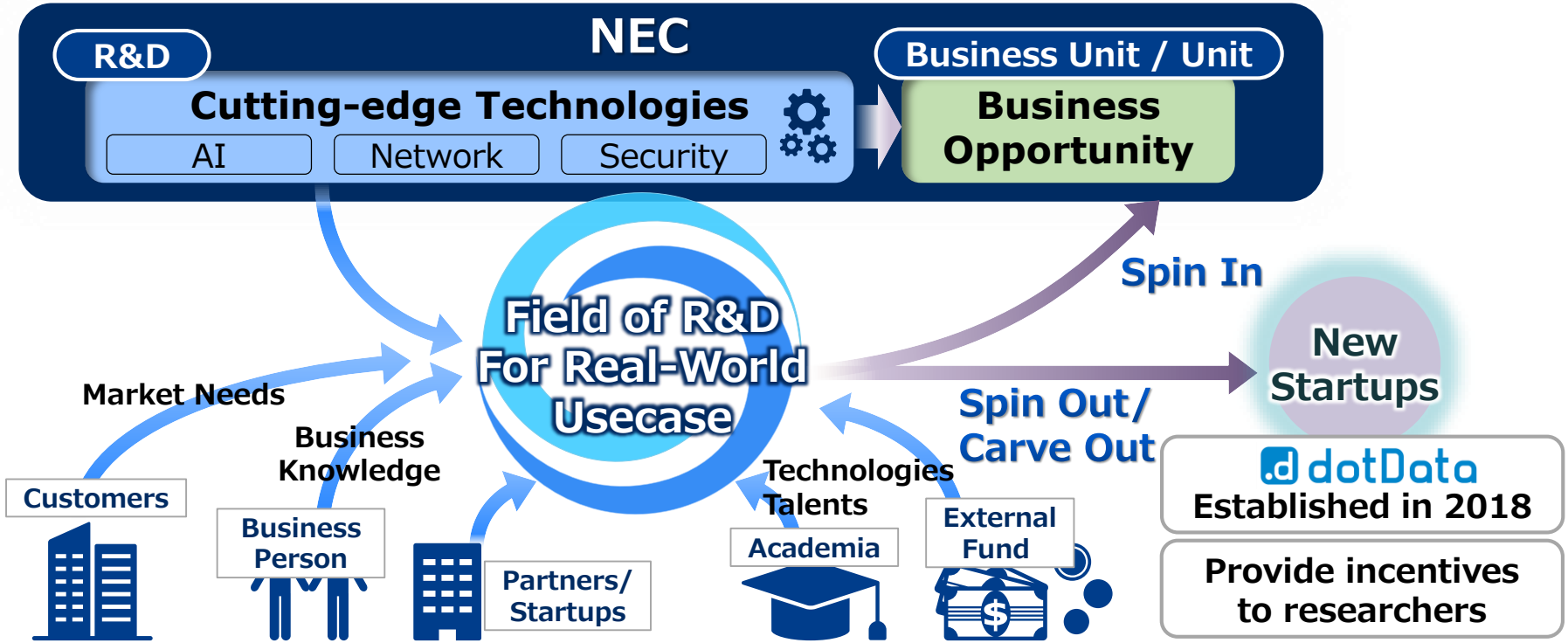
Former distinguished NEC researchers

- **Yann LeCun**
  ACM A.M. Turing Award in 2018 (Highest authority in computer science)
- **Vladimir N. Vapnik**
  Invention of support vector machine
- **Thai Jaw Shen / Yasunobu Nakamura**
  Pioneers of a practical use of quantum computer
- **Ronan Collobert**
- **Jason Weston**
  ICML Test of Time Award
- **Kai Yu**
  Horizon Robotics CEO
- **Leon Bottou**
  NeurIPS Test of Time Award
- **Yidong Huang**
  Prof., Chair of the Department of Electronic Engineering

- **Maintain consistent investments in basic research,** and announced a target of "300 AI researchers" for FY2018 (at IR presentation for FY2016)
  - ⇨ **Achieved a far higher level of 470 researchers and planning to further strengthen peripheral areas**
- Introduced the Compensation Program for Research Fellows (posts for dedicated researchers) for managerial officers in FY2015 and created Research Fellow positions
  - ⇨ Introduced the Selective Compensation Program for Professional Researchers **without limits on incentive for non-managerial employees (younger researchers)**

Ecosystem-oriented R&D with NEC's Cutting-edge Technologies as a Core

Expand NEC's technologies externally at an early phase, taking in technologies and funds from customers/startups/VC to speed up R&D. Open innovation of an Inbound/Outbound fusion type



Aim of Ecosystem-oriented R&D

- **Strengthening resources incl. external funds, and raising new business creation ratio are required for large-scale outcomes**
- **Dare to introduce top-level technology and human resources to strengthen the capability of execution**

Strengthen Resources	×	Raise New Business Creation Ratio	→	Speedy New Business Creation of Large-scale Outcomes
• External funds **(VC, Partners)** • Various internal and external human resources		• Co-creation with No.1 technology as a core • Various domain knowledge		

Management measures of Ecosystem-oriented R&D

Cutting-edge Core technologies	**Invest on cutting-edge technologies that contribute to NEC's core businesses**
Top Researchers	**Appoint AI researchers, incl. Research Fellows, dedicated as a full-time coverage**
Business Talents	**Inject professional business persons to reinforce new business creation**

Ecosystem-oriented R&D by Large-scale Industry-Academia Collaboration

Agree on joint comprehensive research themes with a vision to solve social issues with AI. Promote creation of technological outcomes which is difficult to achieve alone

NEC - AIST

AIST

AI Cooperative Research Lab. (Advanced research)

RIKEN AIP-NEC

理化学研究所

Collaboration Center (Basic research)

- Research of technologies which integrate simulations, which compensate for lack of real-world data on social issues, and AI

Create remarkable technological outcomes

- **Rare event discovery technology (NEC-AIST)**
  AI determines next conditions for simulation while it learns the results of previous simulations. **Shortened periods to detect a fault in an optical device with 100 millionth probability from one week to one day**
- **Logical Thinking AI (NEC-RIKEN-AIST)**
  Shortened periods to find an optimal solution procedure for an abnormal situation at a plant from several years to several days, combining narrowing down a huge number of procedures by way of logical reasoning and reinforcement learning

NEC/University of Tokyo

東京大学 THE UNIVERSITY OF TOKYO

Partnership Agreement for Future AI Research and Education in the Field of Strategic AI

- Research on Brain-Morphic AI platform for an ultra low power AI processing.
- Investigation of ethics and legal systems and promotion of human resource development

Aimed vision of society with AI

- **Future AI vision**
  Future vision of society that supports co-creation of sustainable social value achieved by various people with AI

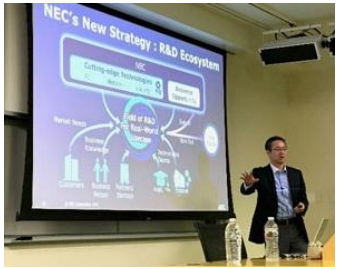
“NEC’s New Strategy for Inbound/Outbound Open Innovation”

- On Stanford University’s request
- Approx. 100 people, incl. students and entrepreneurs, attended

Video: https://www.youtube.com/watch?v=oW1zJ_dUBAk

- Row of questioners for an hour after the lecture
- Introduced the case of dotData

dotData
est. 2018



View lecture on YouTube

https://youtu.be/oW1zJ_dUBAk

Summary

Constantly create No.1 core technologies that contribute to NEC's businesses and social value creation

Provide more than enough opportunities and compensations for top researchers to maintain and strengthen the ability to create technologies

Speedily provide more technological outcomes and commercialized products by way of "Ecosystem-oriented R&D" with NEC's cutting-edge technologies as a core

Establish business competitive advantages