KYUSHU UNIVERSITY

From *Mathematics* To *Mathematics for Industry*

- Self-introduction
- IMI & Math. PhD, Kyushu Univ.
- Examples

Moonshot International Symposium, 18 December 2019

Masato Wakayama
(Kyushu University)

Institute of Mathematics for Industry
Kyushu University

Short Self Introduction

- **PhD (Mathematics)**: Hiroshima University (1985)
- **Research Field**: Mathematics (Representation Theory, Number Theory)

  - @ **Kyushu University:**

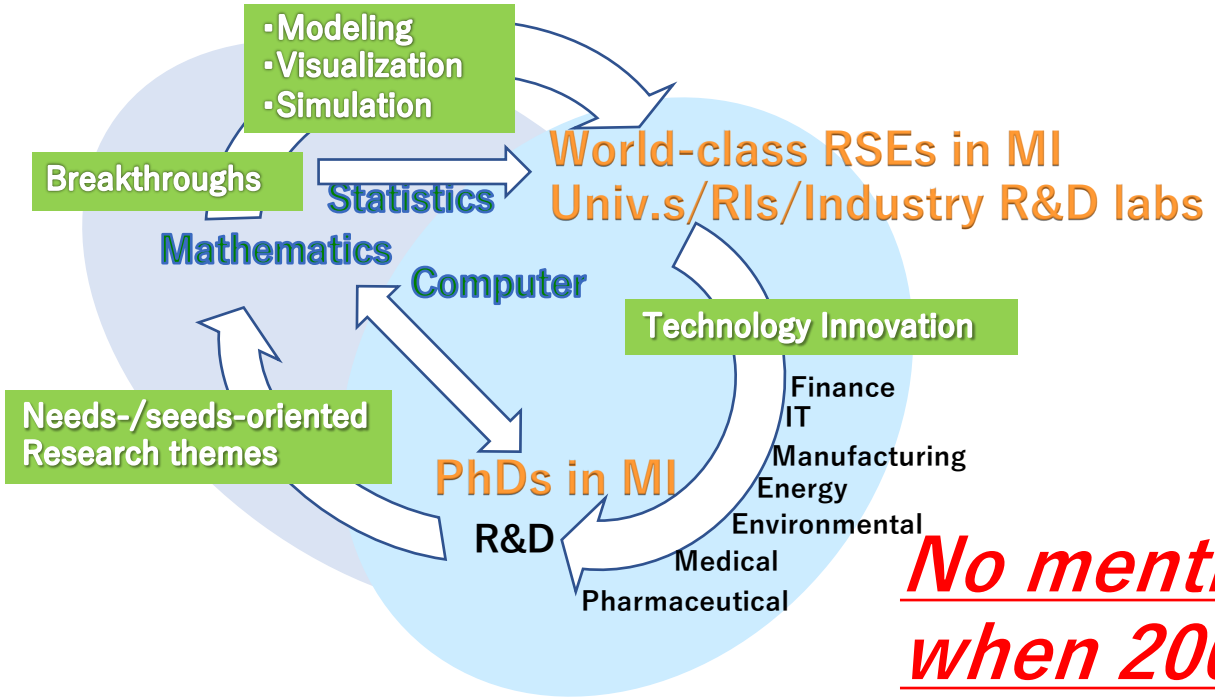
    Professor of Mathematics (1997-)
    Dean of Faculty of Mathematics and Graduate School of Mathematics(2006-2010)
    Leader of the Global COE (MEXT) "Education Hub of Mathematics for Industry" (2008-2012)
    Distinguished Professor (2009-)
    Vice President (Education) (2010-2014)
    Founding Director of IMI (Institute of Mathematics for Industry) (2011-2014)
    Executive Vice President (Research & Industry- Government-Academia Collaboration 2014-2017,
    Global including International affair & Industry- Government-Academia Collaboration 2018-)

- **Other Appointments for "Mathematics - Industry & Sciences":**

- Member: OECD Global Science Forum, Experts Group on Mathematics in Industry (2008-2009)
- Representative: Investigation Project Commissioned by MEXT(Investigation and estimation of promotion of cooperation of mathematics and mathematical science with other fields) (FY2009)
- Chair: Committee of Mathematics Innovation, MEXT, (FY2011 –2015)
- Chair: Asia Pacific Consortium of Mathematics for Industry (2014-)
- Chair: Advisory Council of iTHEMS (Interdisciplinary Theoretical and Mathematical Sciences Program), RIKEN (2019)

  - **Current Research Interest**: Number, Representation Theoretic and Combinatorial Analysis of Theoretical Physics (Quantum Optics) and Application to Graph Theory relating Post Quantum Cryptography

What is Math-for-Industry (From The *GLOBAL* COE Program 2008)



No mention on "AI" when 2008

Math-for-Industry (MI) is a new research area that serves to create advanced technologies in response to industrial needs by innovating flexible and versatile methods in mathematics, statistics & computing. Feedback to mathematics from these activities is highly expected.

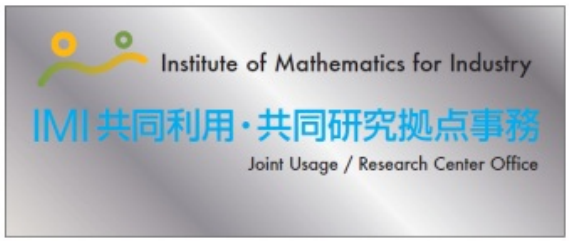
WHY WE ESTABLISHED THE IMI, INSTITUTE OF MATHEMATICS FOR INDUSTRY?

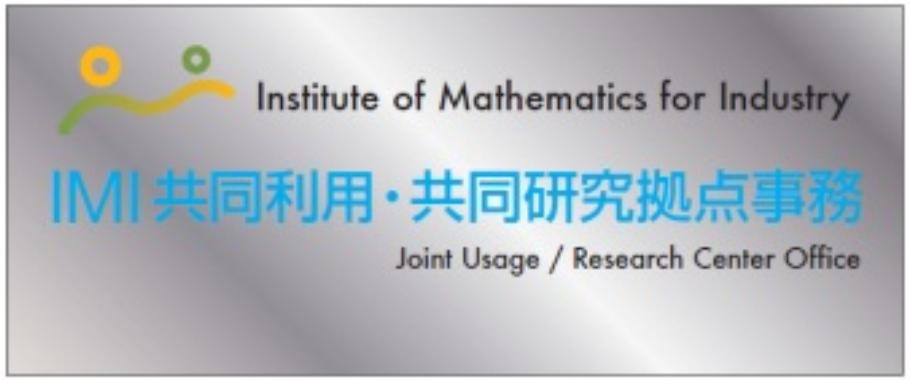
1. There must be a lot of new interesting mathematical problems in industry or our society. In other words, if we are only focusing/prompting researches currently recognized as “pure” mathematics (existing mathematics), mathematics will be shrinking in the future.

2. To explore a new career pass for the PhD in mathematics in Japan. To foster the PhD in mathematics with broad interests and view for applications.

3. We should contribute the society using mathematics developed in the 20th century and so on. Most of mathematics achievements in the 20th century has not been used in engineering, life science, etc.

Abstraction





マス・フォア・インダストリ研究所
（MATH-FOR-INDUSTRY **研究所**）

- Sometimes among Japanese there is a funny confusion about pronunciation in English:

MATH （マス）could sound MASS （マス）in Japanese so that Math-for-Industry has another meaning “Mass Study for Industry”, that is, doing Big-data Study.

Director of IMI:
M.W. (Representation Theory, Number Theory)
→ Prof. Y. Fukumoto (Fluid Mech.)
→ Prof. O. Saeki (Topology, Singularity Theory)

PhD (candidates in Mathematics) in Kyushu University
“Long-term (more than 3 months) Research Internship” 2008-2019

- **Accepted Companies:**

IT & Digital Communication (8), Electronics manufacturing (5), Manufacturing (5),
Insurance (3), Chemical Engineering (3), Others(5)

- **Number of experienced students:**

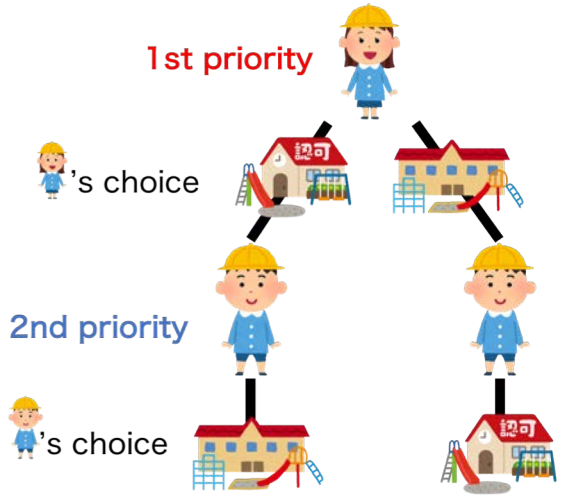
Total (81)= Domestics (69)+ Overseas (12)

- **Research Fields of Students** (upon student’s declaration):

Cryptography (12), Statistics(10), Fluid Dynamics(7), Number Theory (6), Differential Geometry (6),
Numerical Analysis (5), Representation Theory (4), Operator Algebra(4), Algebraic Geometry (4),
Mathematical Optimization (4), Computer Science (4), Topology (3), Partial Differential Equation (2),
Software Science (2), Mathematical Physics (1), Combinatorics(1), Probability Theory (1),
Game Theory (1), Ordinary Differential Equation (1), Information Geometry (1)

Efficient Algorithm for Large-Scale Nursery School Matching Problem

By IMI, Kyushu U. + Fujitsu Lab.



Goal:

Good assignment of children to nursery schools

Difficulty:

Large size + Complex constraints (e.g., brothers)

Solution:

Extensive-form game + Efficient search algorithm

Modeling *Algorithm*

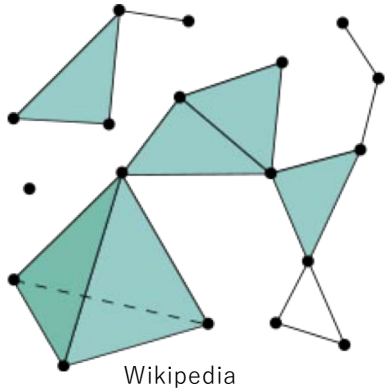
Deep neural networks (DNNs) are powerful but shortsighted

Local
Data driven

ImageNet-trained CNNs are biased towards texture; increasing shape bias improves accuracy and robustness, Geirhos et al. ICLR 2019

Local ∪ *Global*

Persistent homology captures the topology of data



Wikipedia

Global
Maths based

Teach DNNs topology and to think globally

A real-life application:
Detect sinkholes under streets
from radar images

Ground-Penetrating-Radar
(Wikipedia)

Collapse in Hakata
(Nov. 2016 Asahi digital)

prevent this
from happening

Actual radar image

sinkhole

The *homology-assisted DNN* performs at the level of a human specialist with only 40 labeled training data.

Mathematics maximizes the efficacy the small data
when the cost of acquiring data is high (e.g., in medicine and civil engineering)

Fillet Shape for Brazing Joints (2015-2019)

Requirements: Higher quality and weight reduction for aluminum heat exchangers.
Issues: Doing experiments was not sufficient. We needed theory.

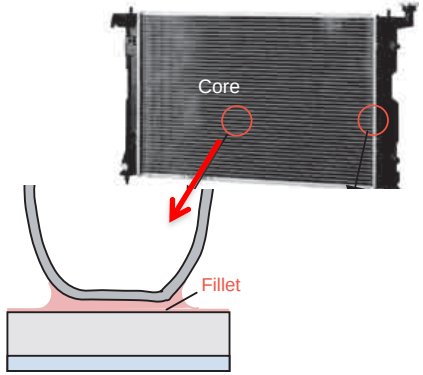
Precision

IMI, Kyushu U.
Koiso: Differential Geometry
Kagaya: Curvature Flow
Matsue: Theory of Computation

Chiba U.:Physics

DENSO
Provide Issues, Programming,
Applications to Brazing

Toyota Central R&D Labs.
Evaluation of Software,
Programming



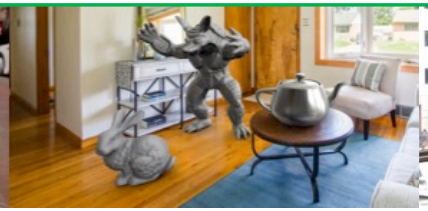
(Source of figures:
S. Teshima-H. Ogawa,' 07.)

Research results: 1. Theorization of the brazing process in mathematics.
2. Accuracy improvement of computation of the shape and estimate of the necessary quantity of the filler metal for various shapes of joints.
3. Offering the new technology to design and develop new products.

CMIC – Computational Media Innovation Centre

VICTORIA UNIVERSITY OF WELLINGTON TE HERENGA WAKA NEW ZEALAND

Collaboration Research with Mathematics started by us, IMI


VISION

Strengthen and enhance New Zealand's position in next generation of media industries through research.

Regularization

Quaternion

MISSIONS

Lie Theory

Develop cutting-edge research to enable future digital media experiences, services and platforms.

Neural Network

Demonstrate value through user-orientated innovation and industry-ready prototypes.

Matroid

Establish a collaboration hub to foster research, commercialisation and entrepreneurship.

Machine Learning

Graph Theory

AVATARIZATION

Facial Animation,
Realistic and stylized rendering
Avatars for games, films, and VR.

ADVANCED PROCESSING

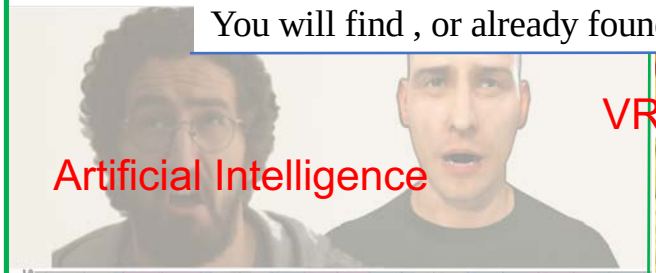
Decimation, Point cloud data, Visualization,
Image and video processing.

Developability

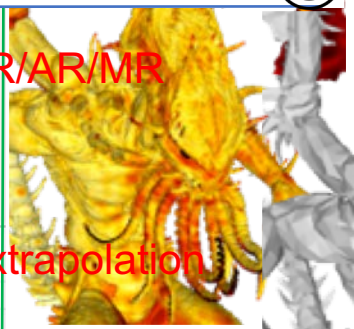
Gröbner Basis

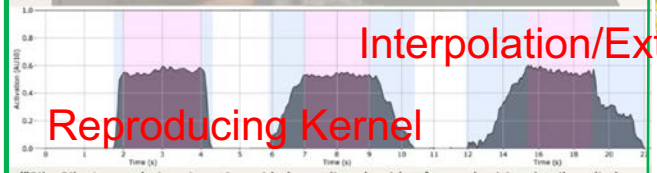
Fractal

You will find , or already found, in some movies



VR/AR/MR





("Piku Piku Interpolation: An artist-guided sampling algorithm for synthesizing detail applied to facial animation", SIGGRAPH Asia 2019 Technical Brief, Nov 2019)

Convolution

Thank you for your attention

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