GPU Technology conference 2018
in Silicon Valley

S8911

Practical Application of Deep Learning in Smart Factory : Visual Inspection System of Semiconductor Laser

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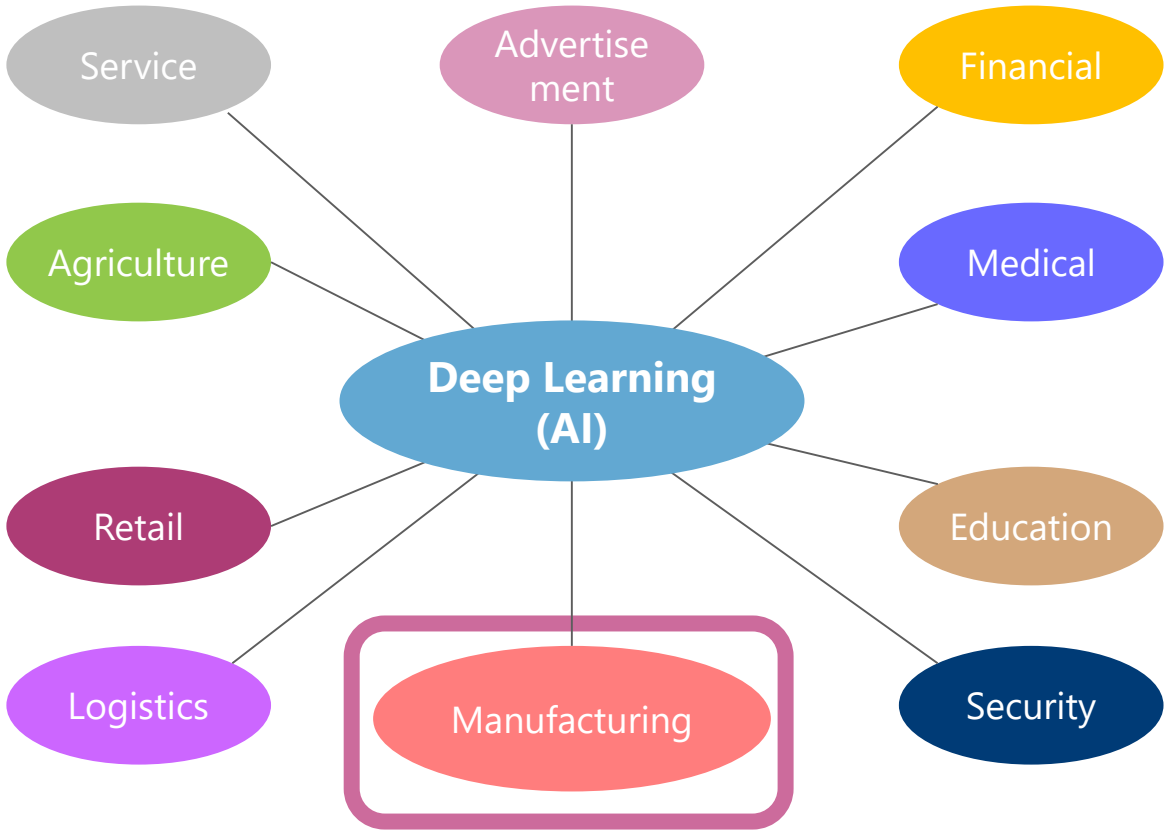
Today's Topic: Deep Learning in Manufacturing



Difficulty of DL in Manufacturing

- Few defective images.
- The requirement is quite different from ordinary DL.
  ex. image size, criteria of classification, etc.

We have successfully overcome these.

- The platform of DL visual inspection system was developed to apply the various production line.
- A visual inspection system has been implemented to actual production line.

1. Introduction of our company
2. Fujikura's "Monodukuri innovation"
3. Fiber Laser
4. Visual inspection using deep learning
5. Other application, future work.

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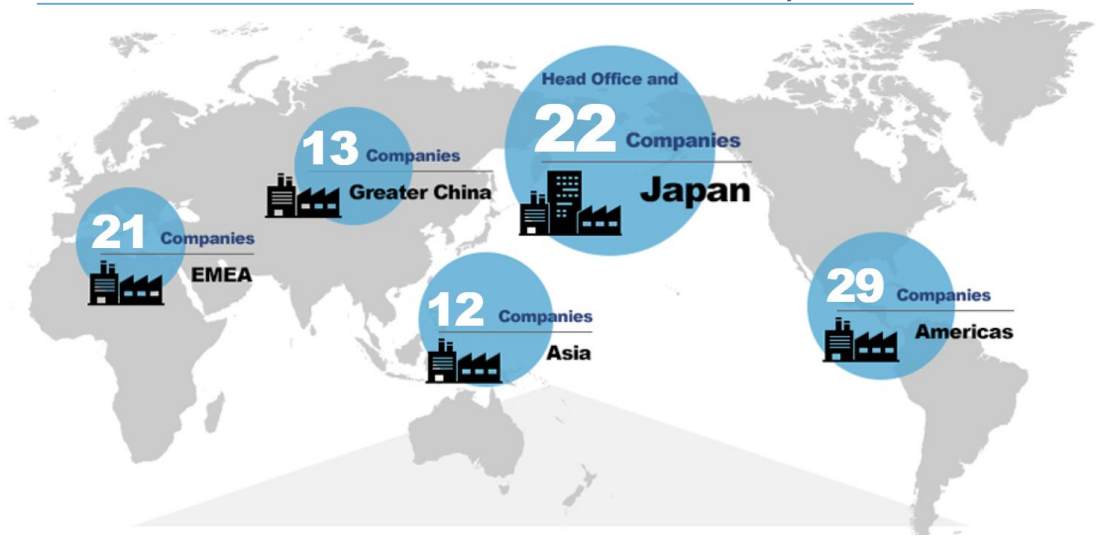
Fujikura Ltd. corporate profile

- Headquarters
  Tokyo, JAPAN
- Founded
  February 1885 (132 Years)

- Head office and consolidated companies



Fujikura Group：29 countries, about 140companyies

- 4 business Areas

Power & Telecommunication Systems Company

Optical Fiber / Optical Fiber Cable / Equipment & Components/Network Device / Optical Parts / Communication Cable / Power Cables/Industrial wires / Accessories /Bare wires / Aluminium wires / Enameled Wires

Electronics Business Company

FPC / Connector / Electronic Wire / HDD Parts / Thermal Product / Sensor

Automotive Products Company

Wire Harness / Automotive related Components

Real Estate Business Company

Fukagawa GATHARIA

History of our company

Fujikura has **130** years history

1885 Establishment

1890 Starting Operation

1923 Restoration after Earthquake and development of Technology

1945 From Post-war Recovery to High Economic Growth

1970 Oil Shock and Fluctuating Market

1991 Globalization Diversification

Now

Toward Forth Industrial Revolution (Industrial 4.0)

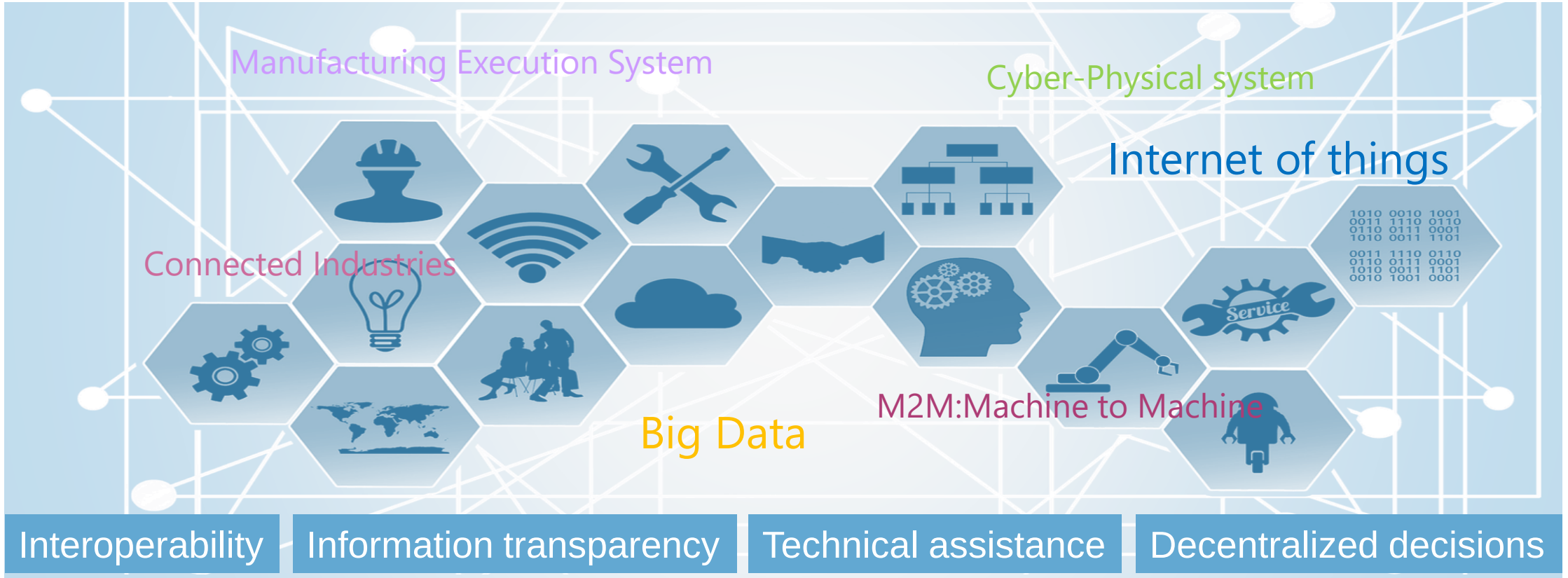
Second Industrial Revolution

Electrification, Mass Production, …

Third Industrial Revolution

Computer, Robot, Automation …

Industry 4.0 & Smart factory



- Highly flexible mass production.
- Condition awareness of machine and process
- Intelligent support of workers
- Product quality
- Just-in-time maintenance and near-zero downtime

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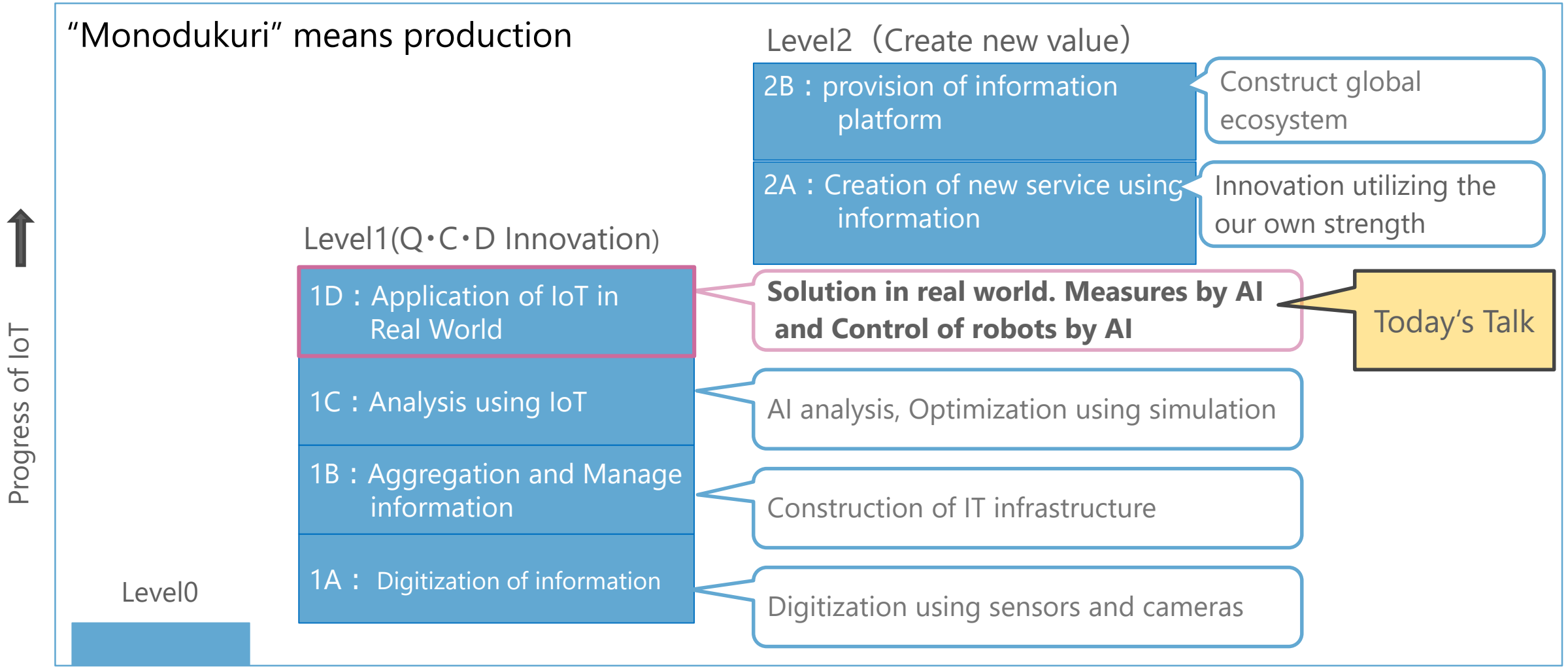
2.1“Monodukuri Innovation” in **Fujikura**

● Our main business field is Level 1:Q・C・D Innovation, Level 2A:Creation of new service

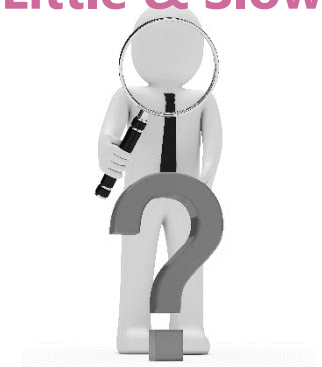


2.2 “Monodukuri Innovation”(Level 0)

Kaizen (business improving) process so far
engineer’s insight, intuition, guess etc.
⇒Total process speed depends on humans processing speed.

Kaizen Process	Grasping the current situation	Identifying the root cause	Testing hypothesis	Counter measure	Verification
SO far	Insight	Intuition guess	Experience Principle	Conventional technology	Measurement by human

Little & Slow



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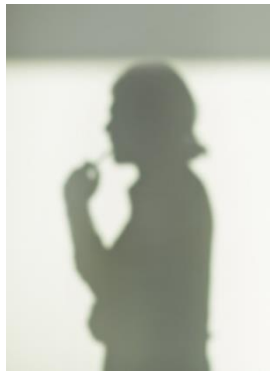

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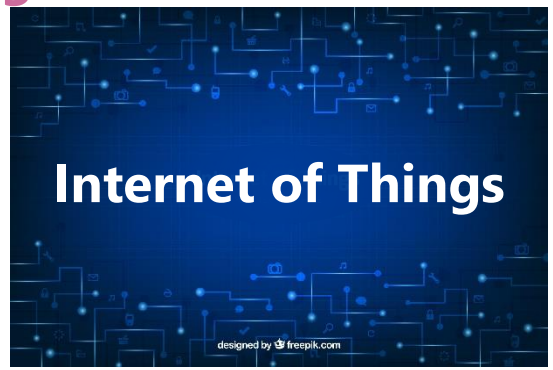
2.2 “Monodukuri Innovation” (Level 1)

●Kaizen process with IoT (without AI)
Human centric process cannot deal a large amount of various sensors data

Kaizen Process	Grasping the current situation	▶	Identifying the root cause	▶	Testing hypothesis	▶ Counter measure ▶ Verification
IoT	**Sensors Cameras**	▶	Intuition guess	▶	Experience Principle	▶ Conventional technology ▶ Measurement by human

Large amount of information



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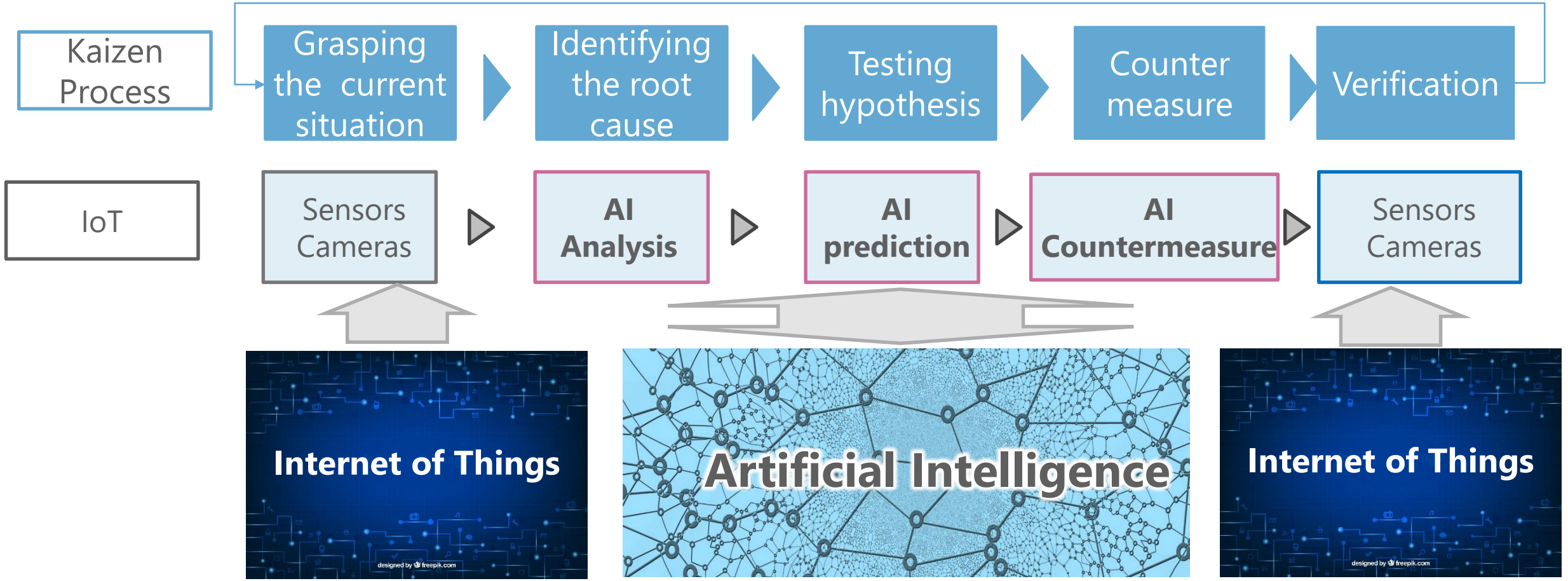
●**Data mining, BI tools, etc.**
⇒**Human centric**
result and speed is limited.

2.2 “Monodukuri Innovation” (Level 1)

●**Unprecedented speed up, effectivity of countermeasure**
⇒AI & IoT is complementary relationship. Promote both as one entity.



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3.1 Fiber Laser

- A fiber laser has excellent beam quality, high efficiency and high reliability.
- Laser diodes are key components of a fiber laser

Fiber laser products

Pulse

Single mode

kW Hi-power

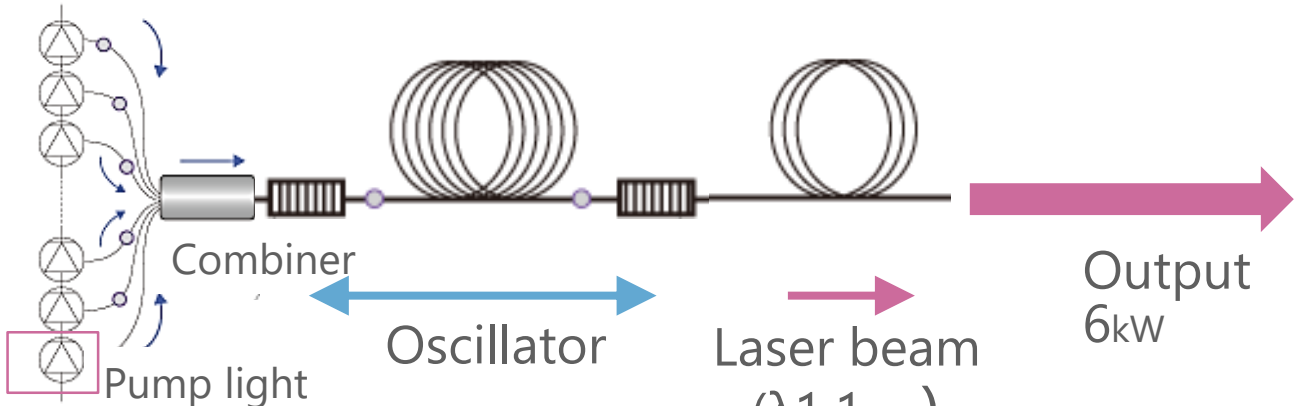
Fiber laser Application

cutting

welding

Surface processing

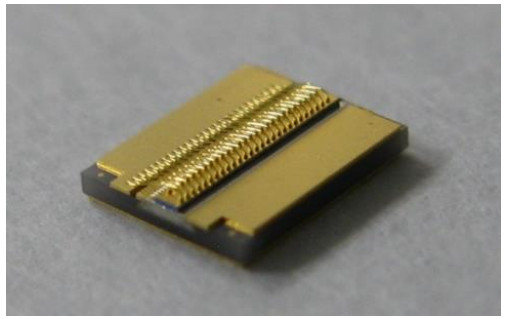
Fiber Laser
Basic Configuration

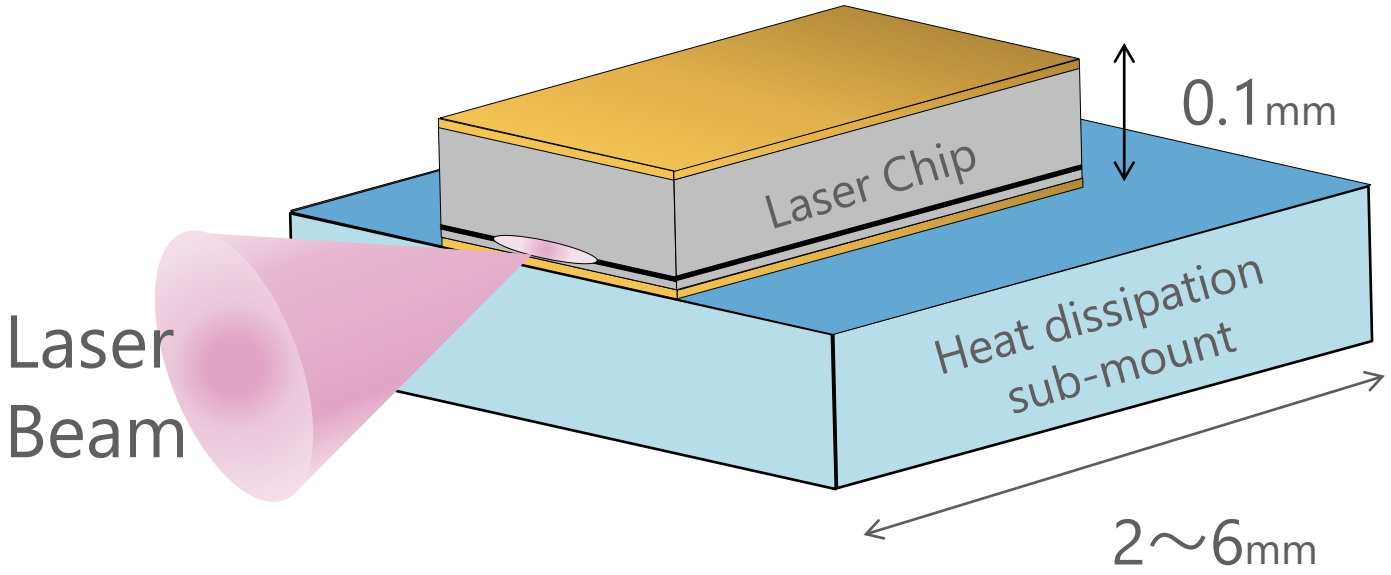


High-power semiconductor Laser

3.2 Pumping LD for Fiber Laser

λ:900nm
Output power:10~20w

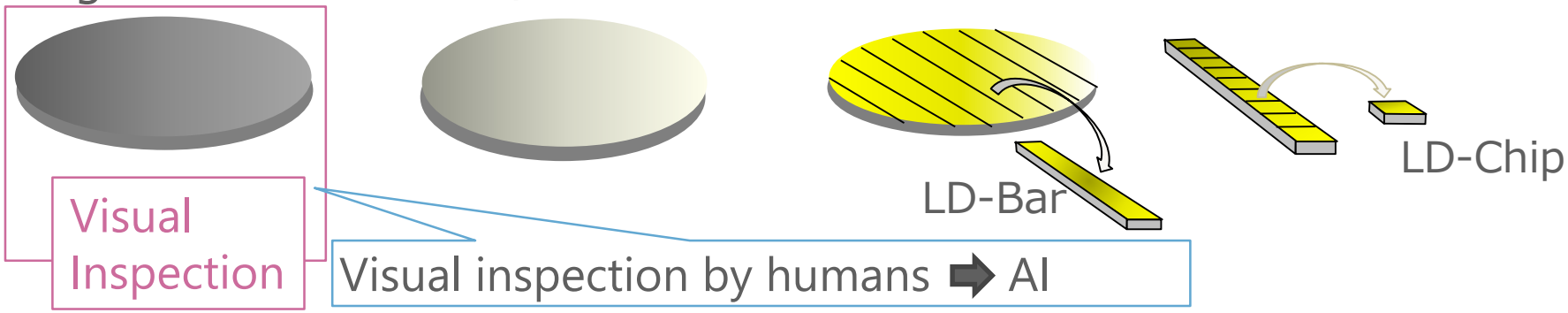




3.3 Manufacturing process of LD for fiber laser

Pre process

Crystal growth → Electrode process → Die cutting

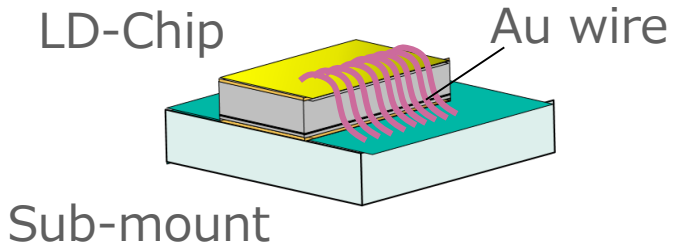


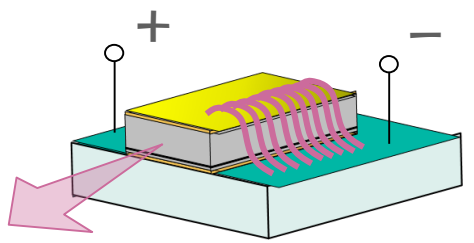
Visual Inspection

Visual inspection by humans ➡ AI

Post process

Assembly → Measurement & Evaluation





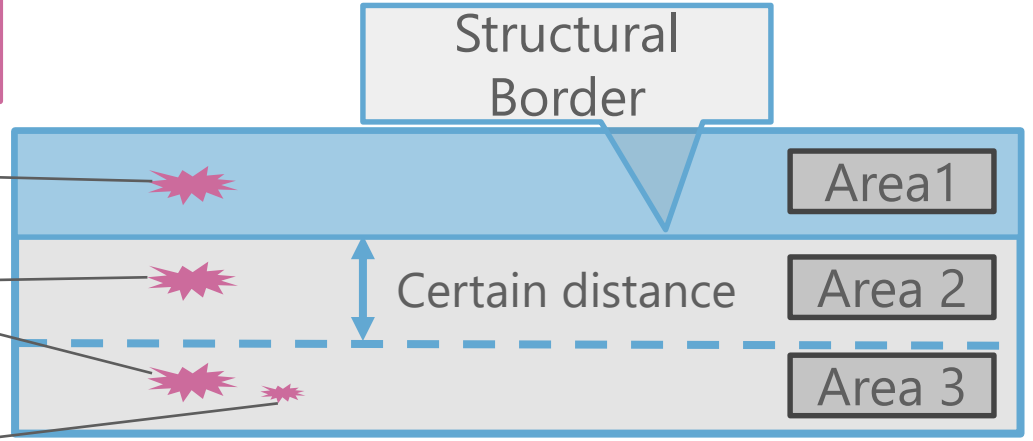
Characteristic inspection

3.4 Visual inspection Criteria of LD chips

1.LD chips are classified into 5 categories (A-E) depending on their defects.
2."Others (defects) mode" needs to be treated and they are classified into different categories depending on their size and position.
3.For multiple defects in an LD chip, it is classified according to a priority of category classification.

		Defect modes			
		mode1	mode2	Others mode	
				Large	small
Occurrence position	Area 1	Category B	Category C	Category D	
	Area 2	-	-	Category E	
	Area 3				Category A

"Others mode" category classification



-For multiple defects in one chip, categorized accordingly to the prioritized category.
Category C > Category D > Category E > Category B> Category A
A LD chip with no defect is categorized into A

This classification was done by skilled workers. → AI

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4.1 Overview of visual inspection

●Purposes

1.Promotion of automatic inspection

2. Accumulation of knowledge and skills of AI

Improve competitiveness of manufacturing company (Monodukuri Innovation)

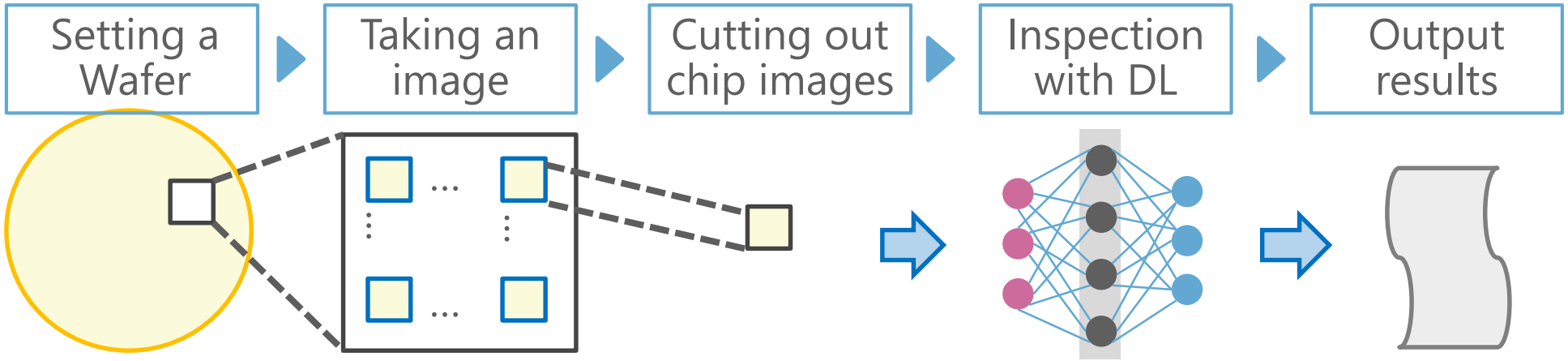
3.Productivity and quality improvement of semiconductor lasers

Improve competitiveness of Fiber Laser products

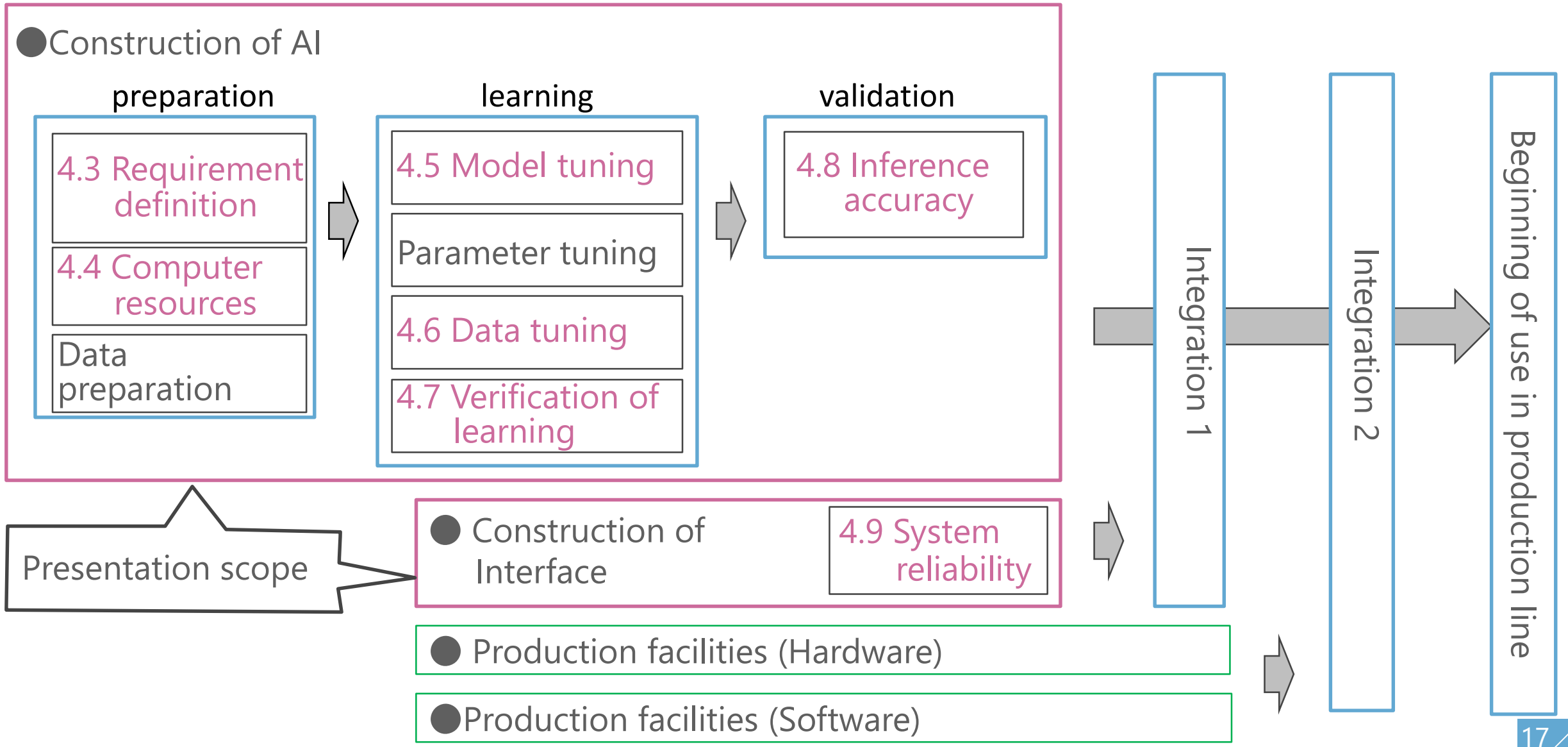
●Organization of Project Ai

1. User (Image preparation) — Optenergy, Inc. (Fujikura group)
2. AI technology development — Fujikura Ltd. R&D dep.
3. System development — Fujikura Ltd. Production facilities dep.

●process overview



4.2 System development process



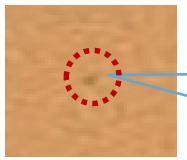
4.3 Requirement in visual inspection system

● The special requirement of our DL system different from ordinary DL is shown.

No	Special requirements	Action, issue	Slide
1	The large ratio of chip size to defects size(1:500000) → Size is 30times larger	Pixel size Computer resources	4.4
		Deep learning model for large image	4.5
2	There is "Others" mode	"Others" modes is classified into sub modes.	4.6
3	Defects is classified into different class depending on the size and position	Create data base to manage image data	
4	There are few images in some failure categories.	data augmentation	
5	Explanation for AI classification	heat map	4.7
6	Implementation in production line	High reliability	4.9

4.4 Pixel size and computer resources

●Pixel size ⇒ minimum defects：2x2 pixels, the whole chip：2million pixels



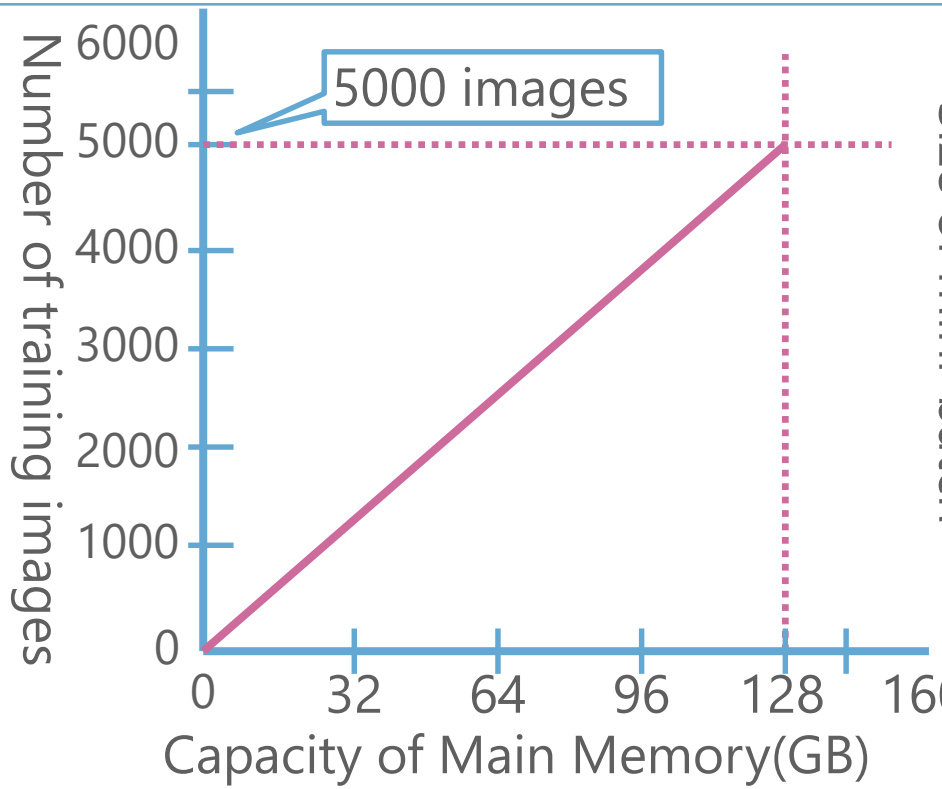
Minimum defects 2x2pixels
⇒ Minimum size

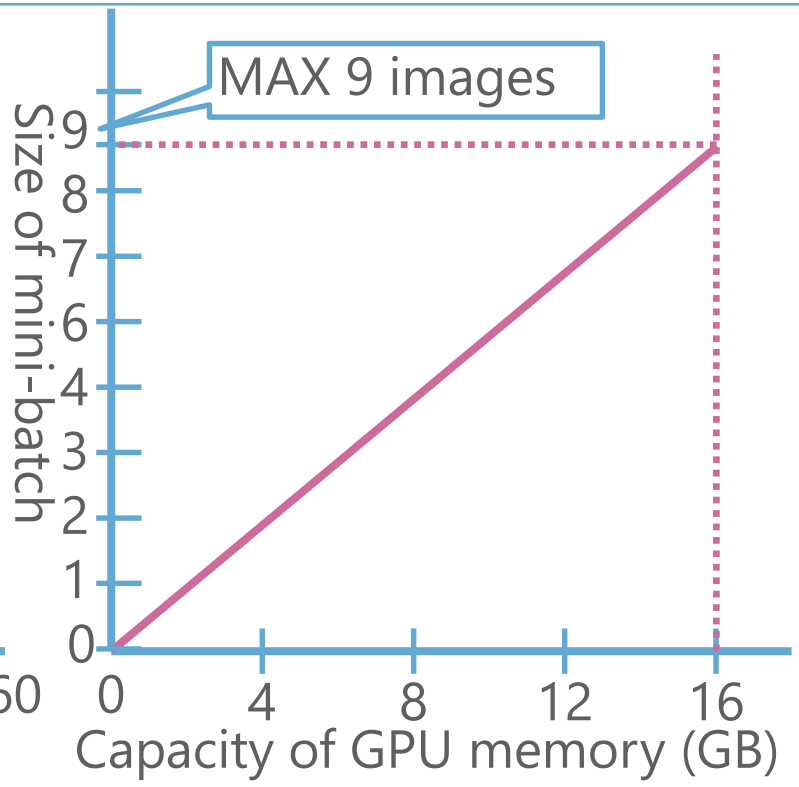
Half a million times large

The whole chip

2million pixels
⇒30 times large size
(typical case: 256x256=
65 thousands)

DGX-1 with Tesla V100	
Performance (GPU FP16)	1 peta FLOPS
System memory	512GB
GPU memory	16GB/GPU





4.5 Tuning the network model

●General deep learning model doesn't work ⇨ Network model is build from scratch

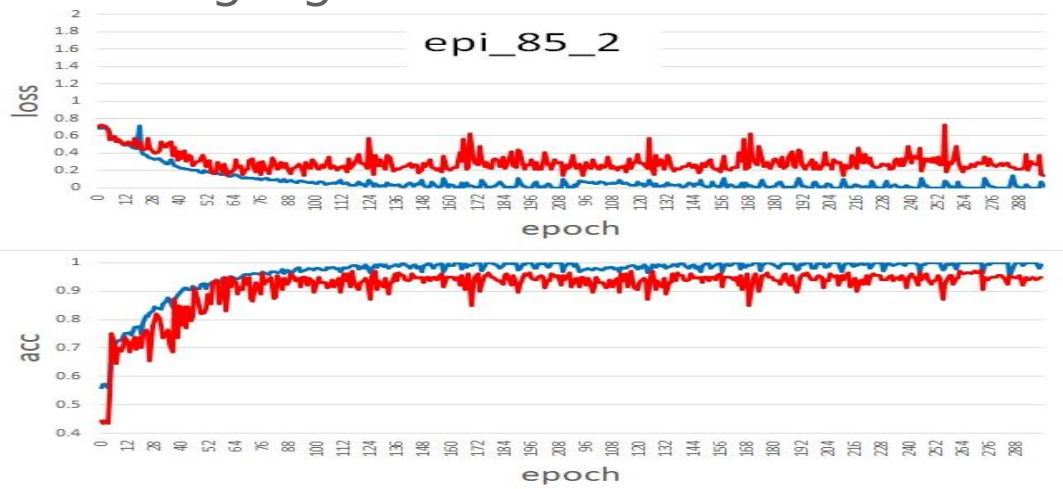
General model (ex. VGG) ⇨ **NG**

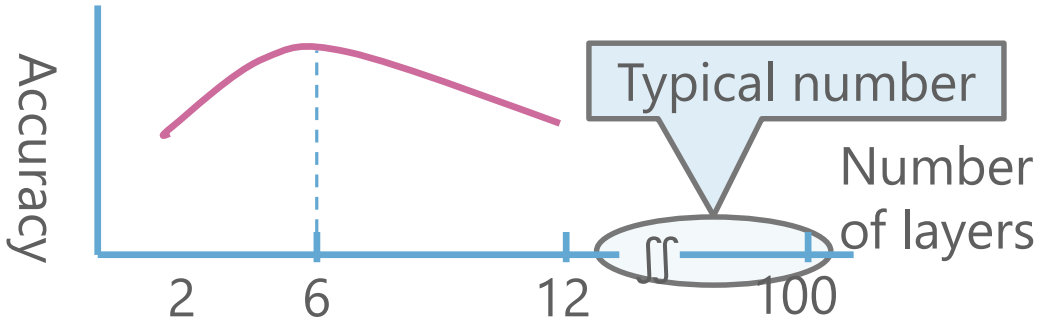
Varying the layer, filter size, etc.

Checking Training log & heat map

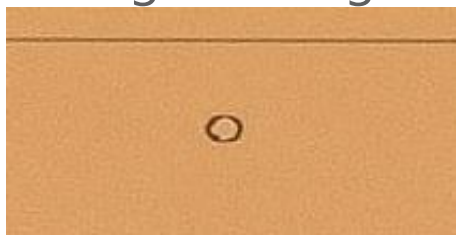
Select the best network config.

●Training log

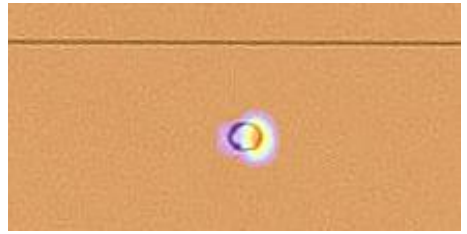




Original image



with feature heat map



4.6 Data tuning

- Create data base to manage image data and utilized for improvement.
- For insufficient image data sets, data augmentation (LV1, 2) is performed.

- Data base item (example)

Chip ID	Lot No.	Defect mode	**Defect Sub mode**	Defect Position	Defect size	Augmen tation	Inference results	…

Image **DB**

Training, inference results

		Defect modes			
		mode1	mode2	**Others mode**	
				Large	small
Occurrence position	Area 1	Category B	Category C	Category D	
	Area 2	-	-	Category E	
	Area 3				Category A

More than 10 Sub modes

4.6 Data tuning

- Create data base to manage image data and utilized for improvement.
- For insufficient image data sets, data augmentation (LV1, 2) is performed.

- Data base item (example)

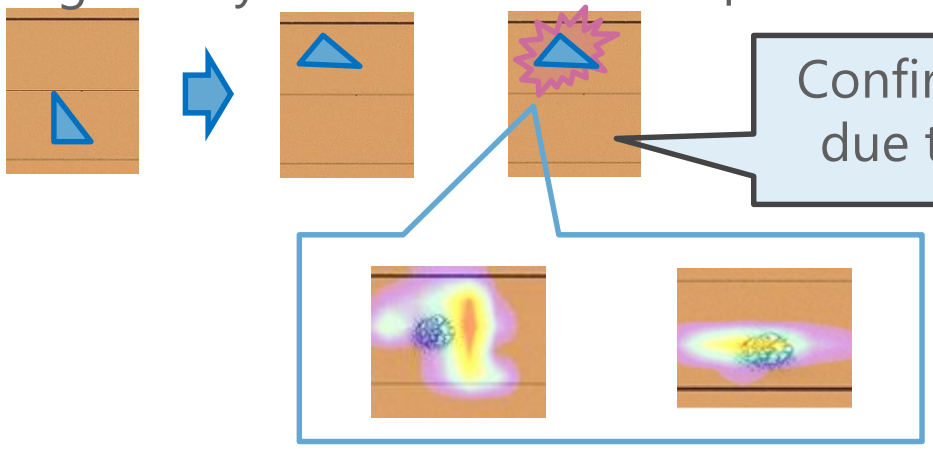
Chip ID	Lot No.	Defect mode	Defect Sub mode	Defect Position	Defect size	**Augmentation**	Inference results	…

Image **DB**

Training, inference results

- LV1:General data augmentation
  (Rotaion,up-down,Left-Right inversion, etc.)
- **LV2:synthesized image data is used.**

Original Synthesized +heat map



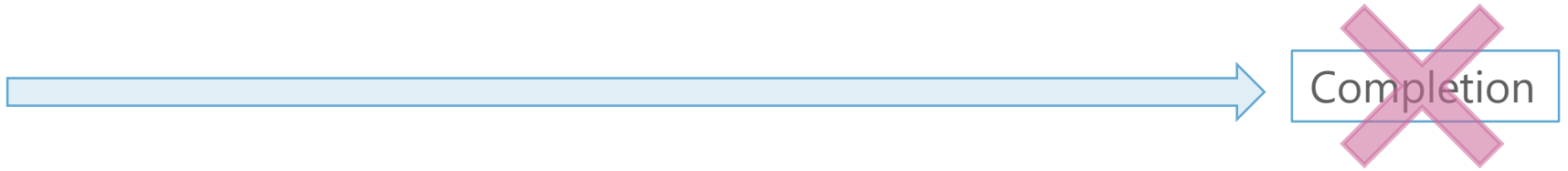
Confirm **No adverse effect** due to synthesis images

4.7 Verification of learning

- Not only the judgment of classification accuracy
  confirm that the heat map shows the correct position.
- Improve accuracy by eliminating discrepancies one by one

1.Human Judge
＝X

2.DL inference
＝X



4.7 Verification of learning

- We check the heat map for consistency during the inspection.
- Improve accuracy by eliminating discrepancies one by one

DL judge this cat. X by chance based on different point.

1.Human Judge
＝X

2.DL inference
＝X

3.Feature map

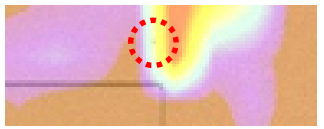
DL inference

human

discrepancies

DL focuses on a different point from the human's judge point.

4. Improvement
Inferring what kind of error occurs from feature map
⇒Increase the similar images (including synthesized images)
⇒Confirm the effect



4.8 Inference results

- The 98% high accuracy has been achieved. That exceeds human accuracy (95%).
  ⇒ Pass-Fail classification:98%, Category classification:95%

- Pass/Fail accuracy

Test data Pass:47% Fail:53%		DL system	
		Pass	Fail
Answer	Pass	46%	1%
	Fail	1%	52%

Total:98%

It exceeds Human classification accuracy (95%)

- Category classification accuracy

	Pass		Fail		
category	**A**	**B**	**C**	**D**	**E**
accuracy	97%	100%	95%	86%	88%

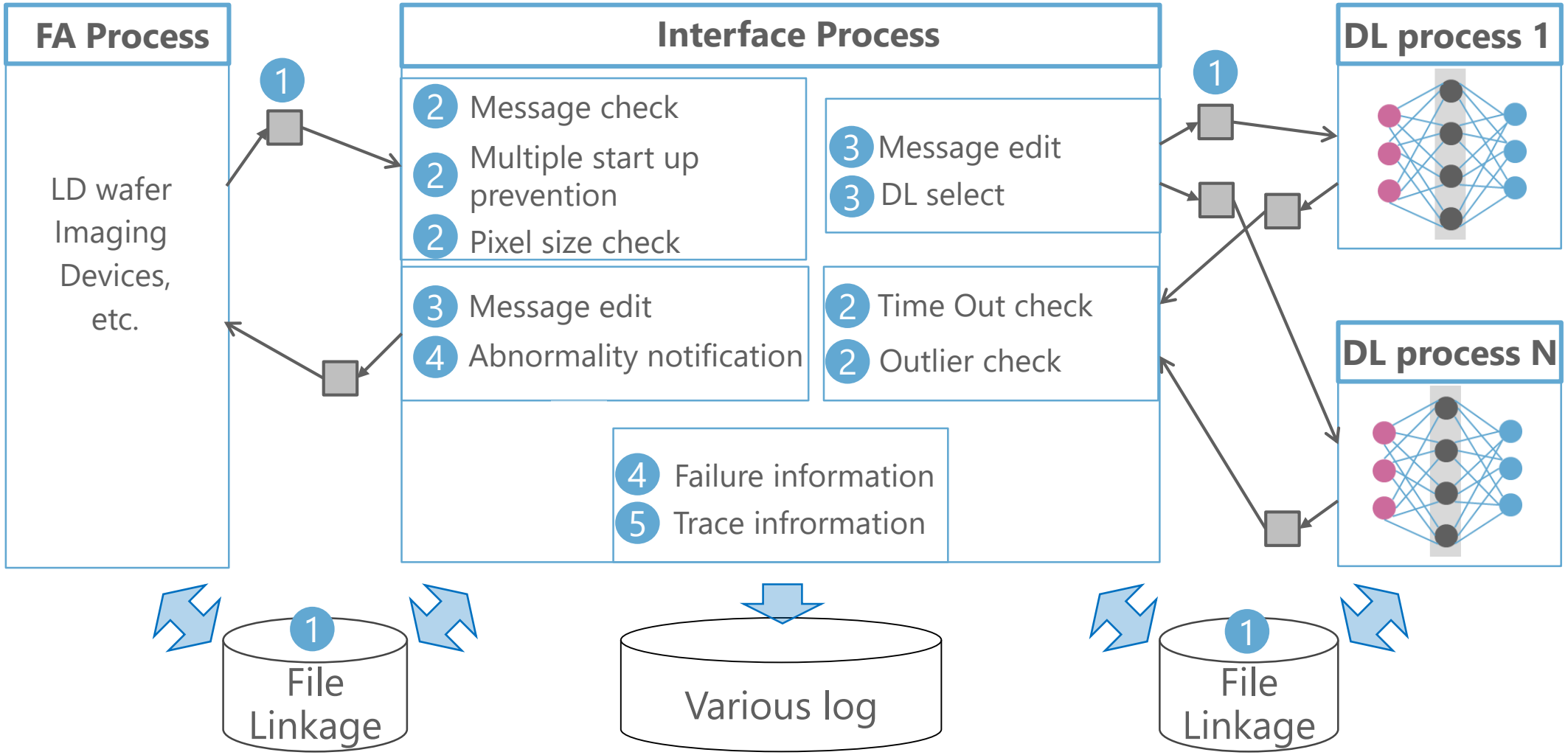
Consider actual occurrence distribution

Weighted accuracy 95%

4.9 System design for reliability, extensibility, etc.

- Implementation in production line

1 Loose coupling 2 High reliability 3 System extensibility
4 Failure recovery 5 Traceability



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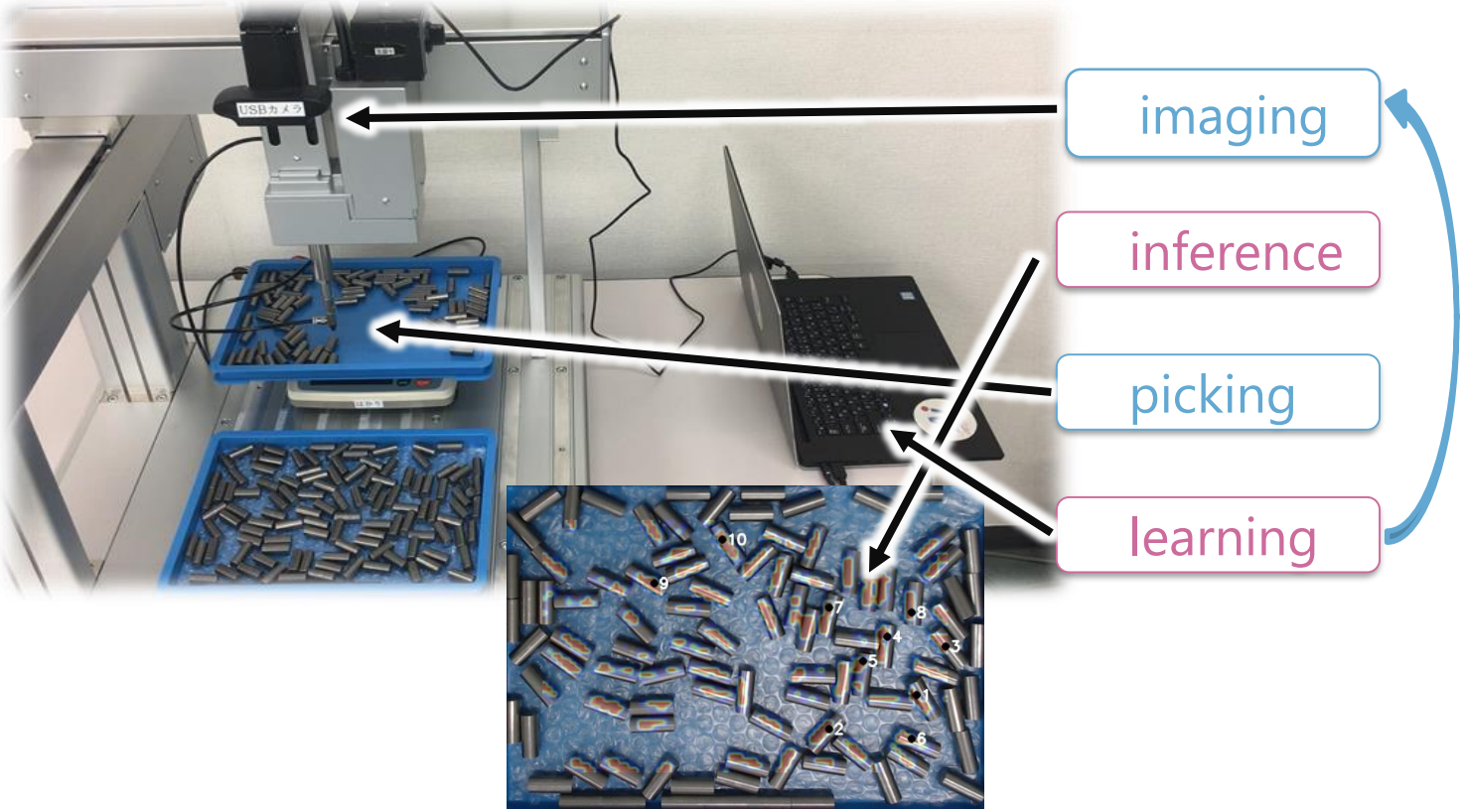
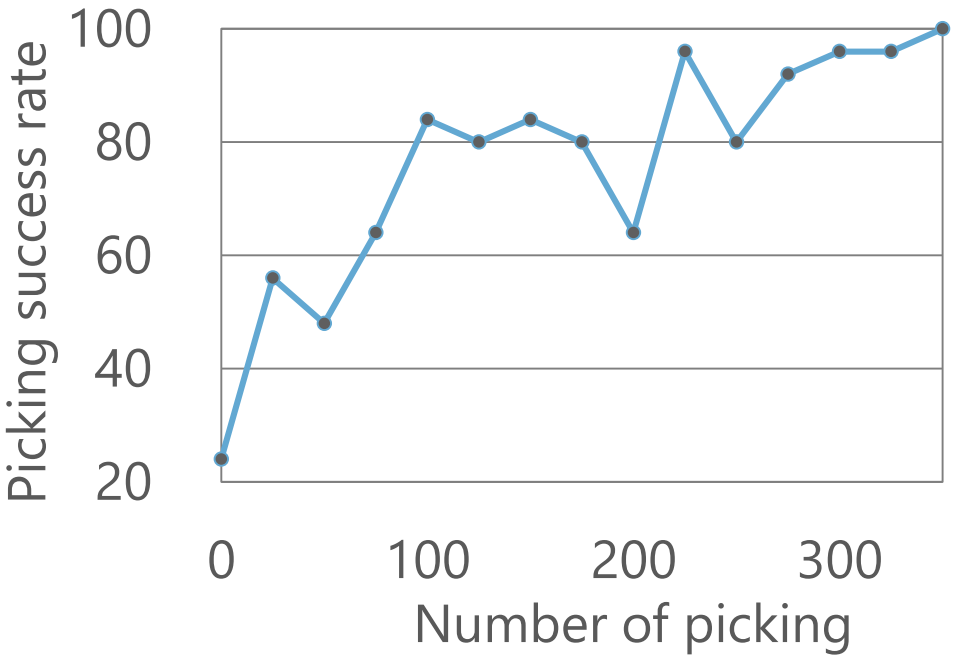
5.1 Robot picking with AI

●The robot autonomously obtains the image of the objects, recognizes the image by deep learning, judges based on the recognition result, and decides the next action.





With 300 picking, more than 95% of success rate is achieved

●Future application of robot picking technology

・・・Motion capturing, autonomous robot

5.2 Summary

- Fujikura is pushing forward “Monodukuri Innovation”
- Case study of AI

①Visual inspection systems of LD with deep learning

- Deep learning with large-scale images

-The limitations of computer resources.
-Model tuning for the original image dataset

- Efforts to improve the accuracy

-Managing the training image data by Database
-Use of synthesized images for too little sub category.
-Data tuning with feature heat map

②Robot picking with AI

- For future applications

-Motion capturing, autonomous robot

Thank you for your kind attention

We are recruiting colleagues to work together with us!!

fjk.career@jp.fujikura.com

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