An Interactive Image Mining System for Engineering Design and Manufacture

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Outline

1 Introduction : Needs of image mining

2 Related works and a problem

3 Proposed image mining system

4 Applications in manufacturing domain

5 Conclusions

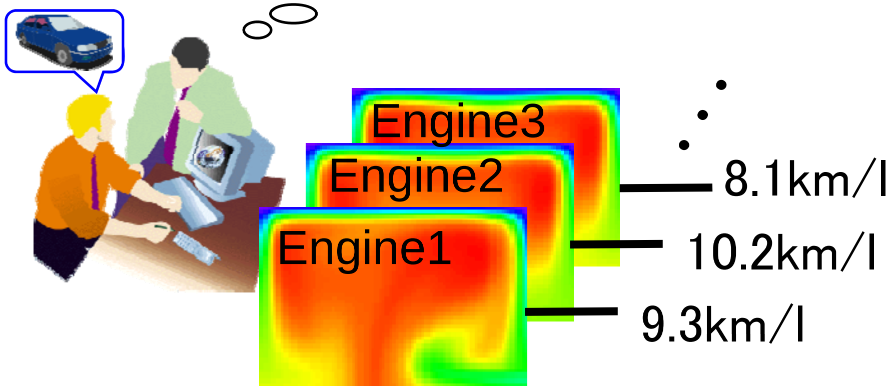
Introduction

- **Needs of image mining in manufacturing domain**

Examples

Engine design of automobiles

What shape should be adopted for fuel-efficient engine?

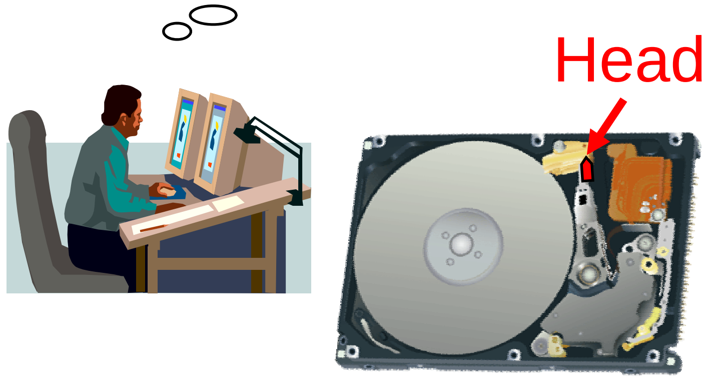


Fuel concentration distribution

Gas mileage

Manufacture of new-type HDD heads

What shape of the head should be adopted to achieve higher yield?

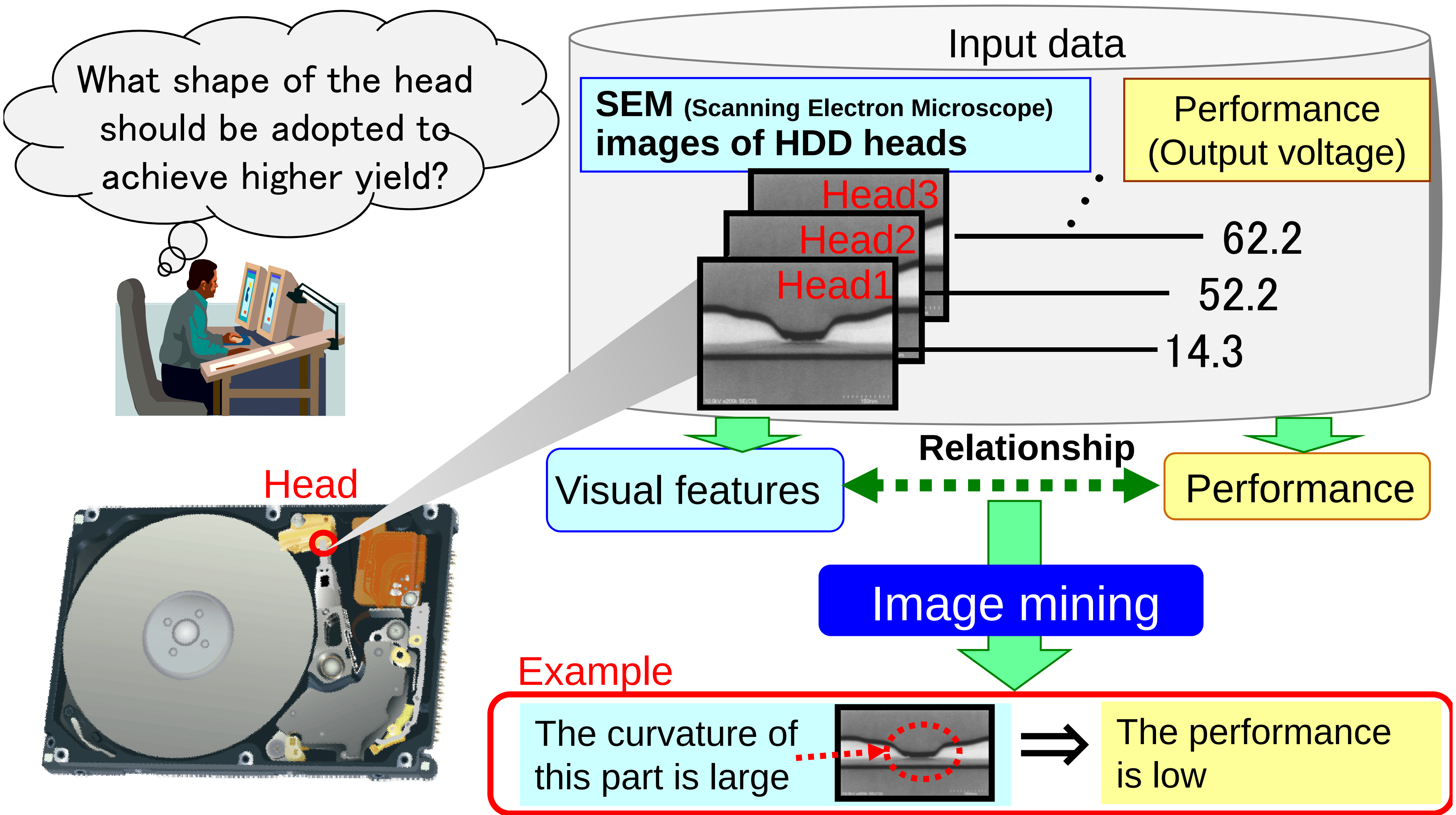


HDD (Hard Disk Drive)

Knowledge discovery from image databases

Manufacture of HDD heads

- **Discovering relationships between the head shape and performance**



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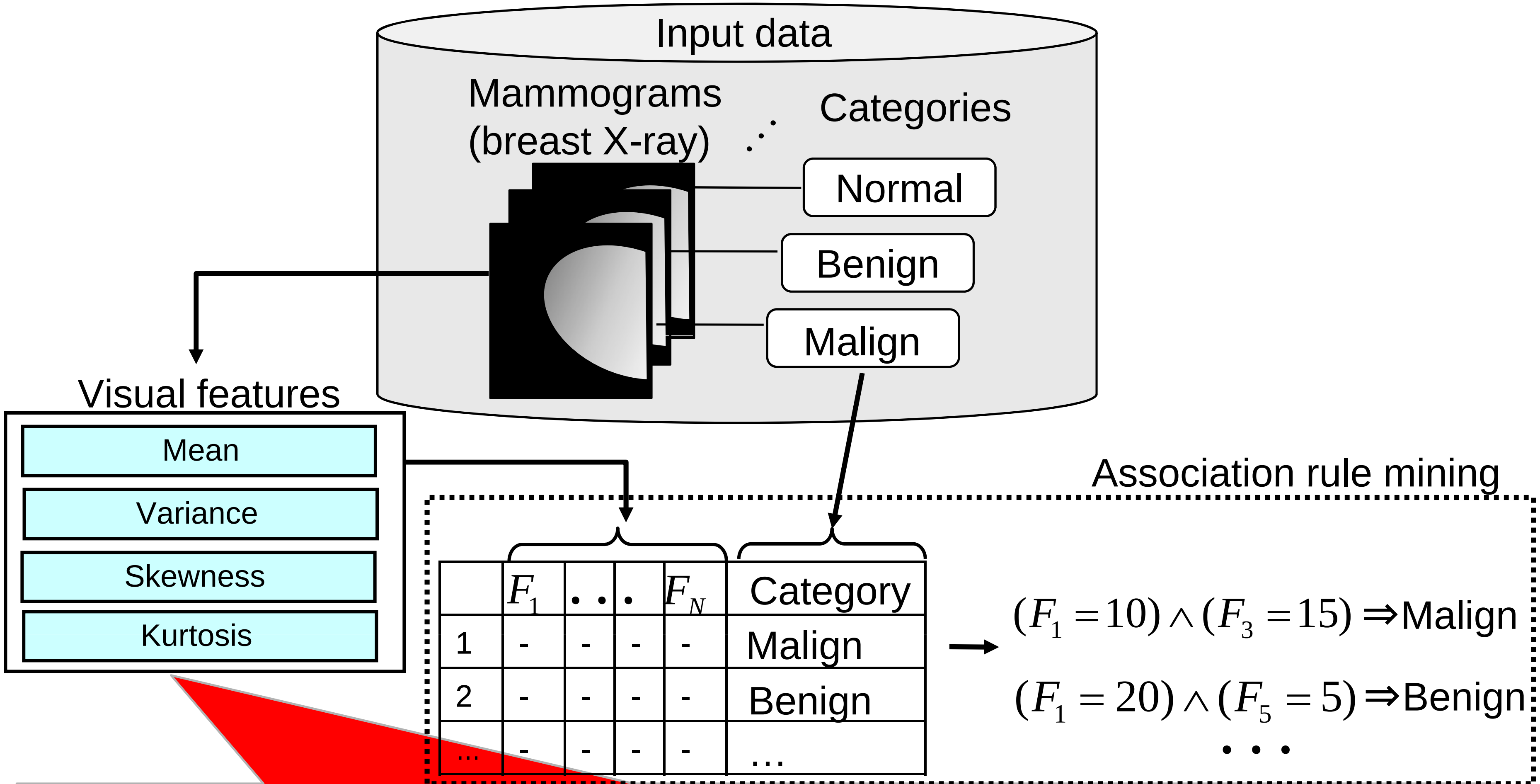
Related works of image mining

Image Mining from medical images【Zaïane 02】



Domain experts can empirically guess in advance the types of visual features which could affect the categories using domain-dependent heuristics.

Related works of image mining

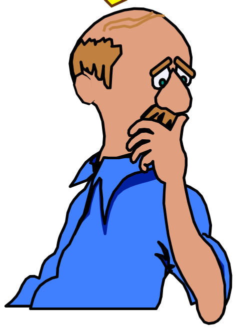
1. f-MRI images【Tsukimoto 01】
   - Relationships between active areas in f-MRI images and finger movements
2. Climate images【Stolorz 95, Katayama 99, Kitamoto 01】
   - Relationships between typhoon images and the paths of the typhoon
3. Aerial images【Tesic 03】
   - Relationships between fields and amount of crop
4. Medical images【Zaïane 02】
   - Relationships between mammograms and diagnosis

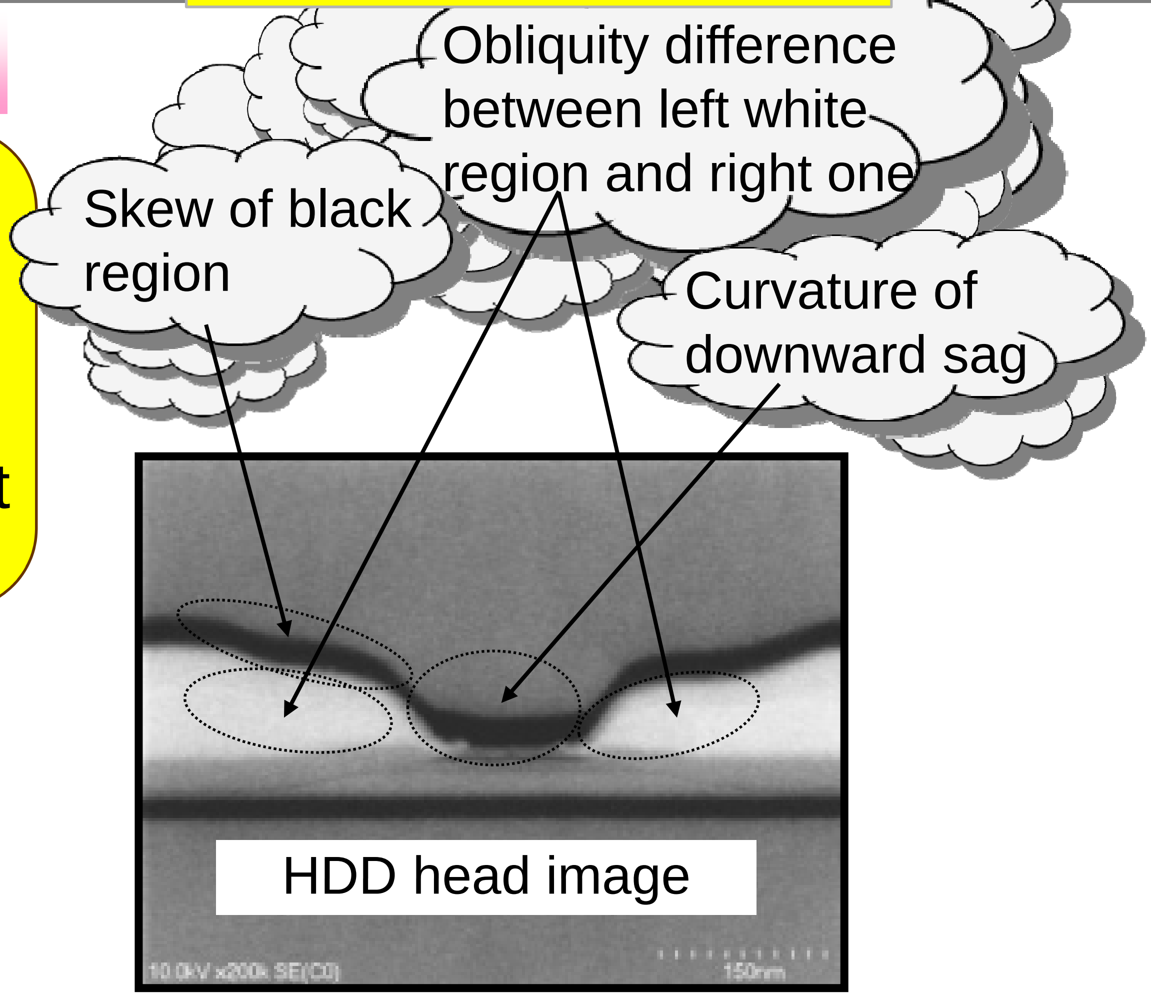
Problem

A large number of types of visual features!

New-type HDD application

We can not guess in advance what types of visual features could affect performance, when domain-dependent heuristics are unknown.





It is very difficult to determine the types of visual features which could affect the performance.

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Proposed image mining system

- **It is difficult to compute automatically the types of visual features which affect performance because a large number of types of visual features exist.**

- **Our approach**
  - **A system aids users to explore images to determine the types of visual features which affect performance.**

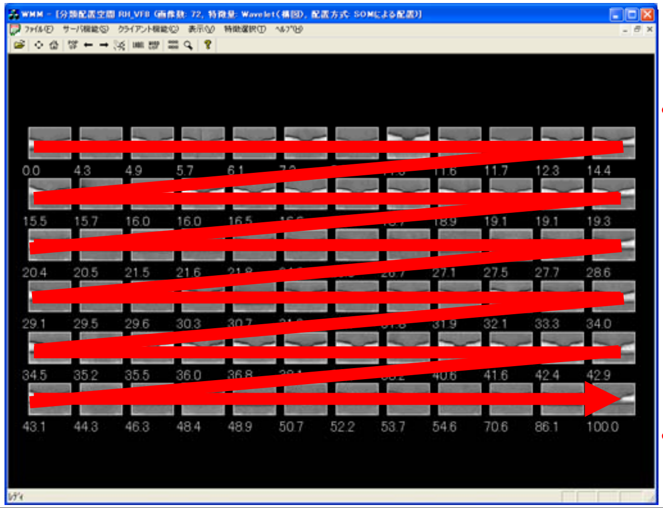
Proposed image mining system

■ What is important to aid users?

- To enable users to browse a large number of images smoothly
- To arrange images to enable users to discover relationships between visual features and performance
- To enable users to change arrangements of images interactively

Our system arranges images in a virtual 3D space.

Examples Arrangement in ascending order of performance



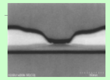
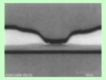
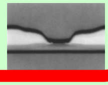
Low performance

Users can compare images with low performance with images with high performance to determine the types of visual features which affect the performance.

High performance

Arrangement of images

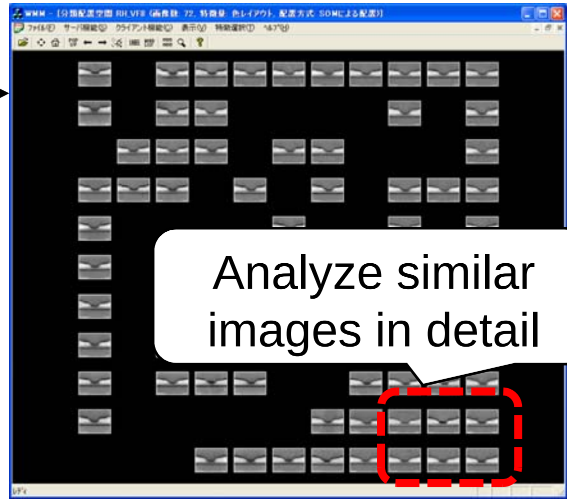
Users determine the types of visual features which affect performance.

Image	Performance A	Performance B	..
	15.1	323.1	..
	20.9	432.2	..
:	:	:	:
	12.1	255.9	..

(3)Arrangement by shape feature

$(d_{11},d_{12},\ldots,d_{1n})$
$(d_{21},d_{22},\ldots,d_{2n})$
$(d_{31},d_{32},\ldots,d_{3n})$
....

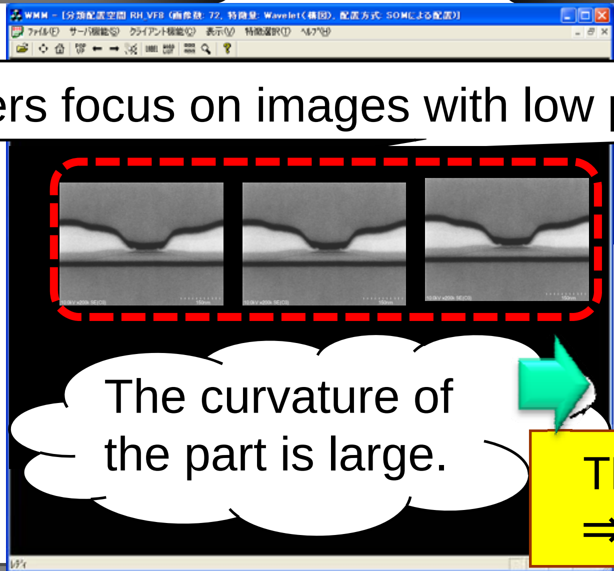
Arrangement of images on a plane by self-organizing map



(1) Ascending order of performance

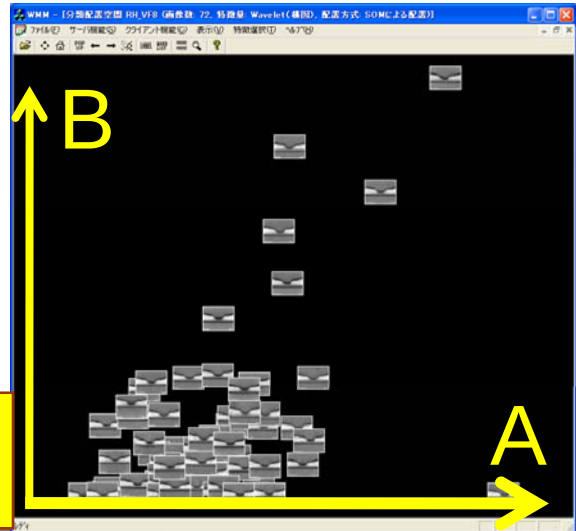
(2) Arrangement by performance A and B

When users focus on images with low performance



Formulating hypothesis

The curvature is large
⇒ Performance is low



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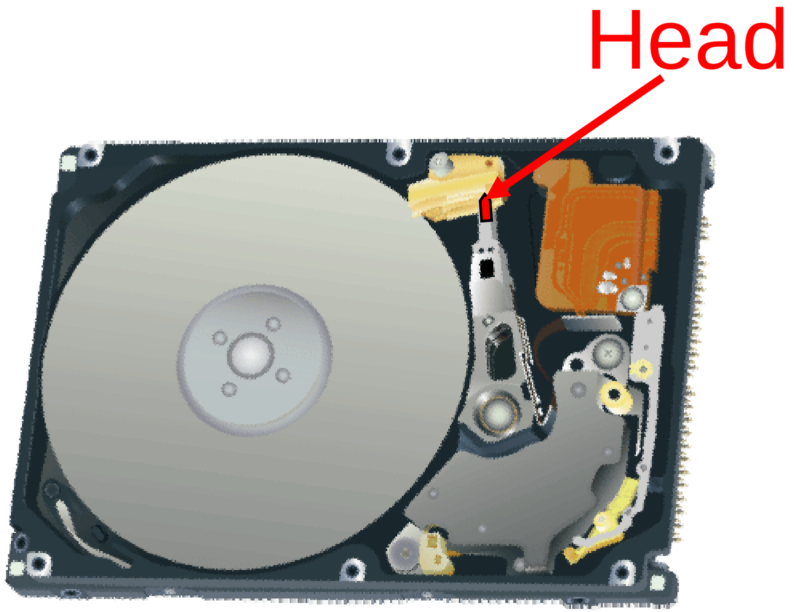
Industrial applications

- **Two industrial applications of HDD heads**
  - **(1) Scanning electron microscope (SEM) images**
  - **(2) Computer simulation images**



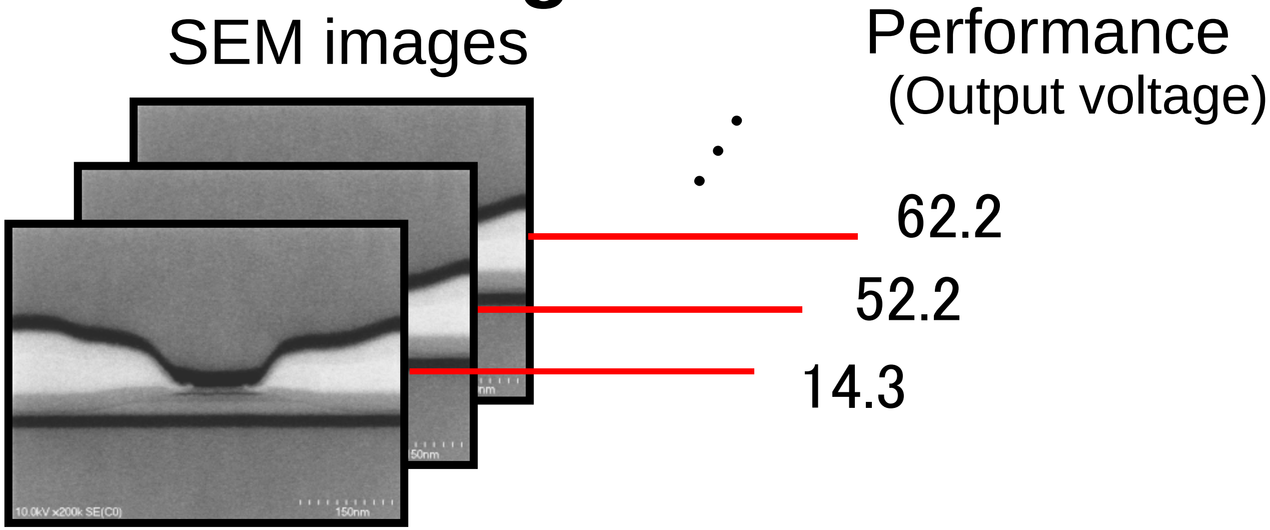
(1) SEM images

Boosting yield is important in the manufacture of new-type HDD.

Goal

- **To discover relationships between the shape feature in SEM images and the head performance**

Input data: 72 images

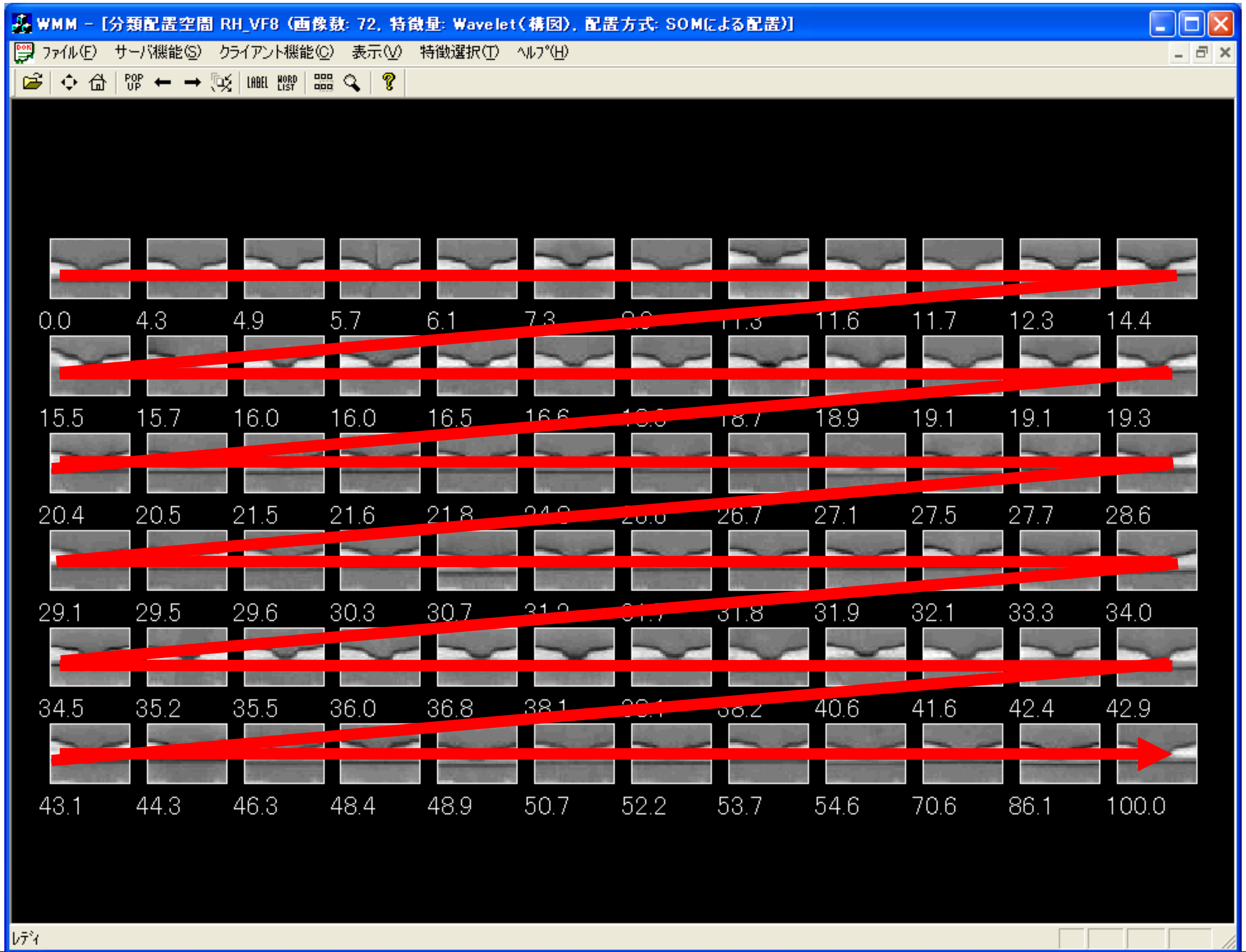


- Air-bearing surface of the read core of a head
- Multilayered thin films

(1) SEM images

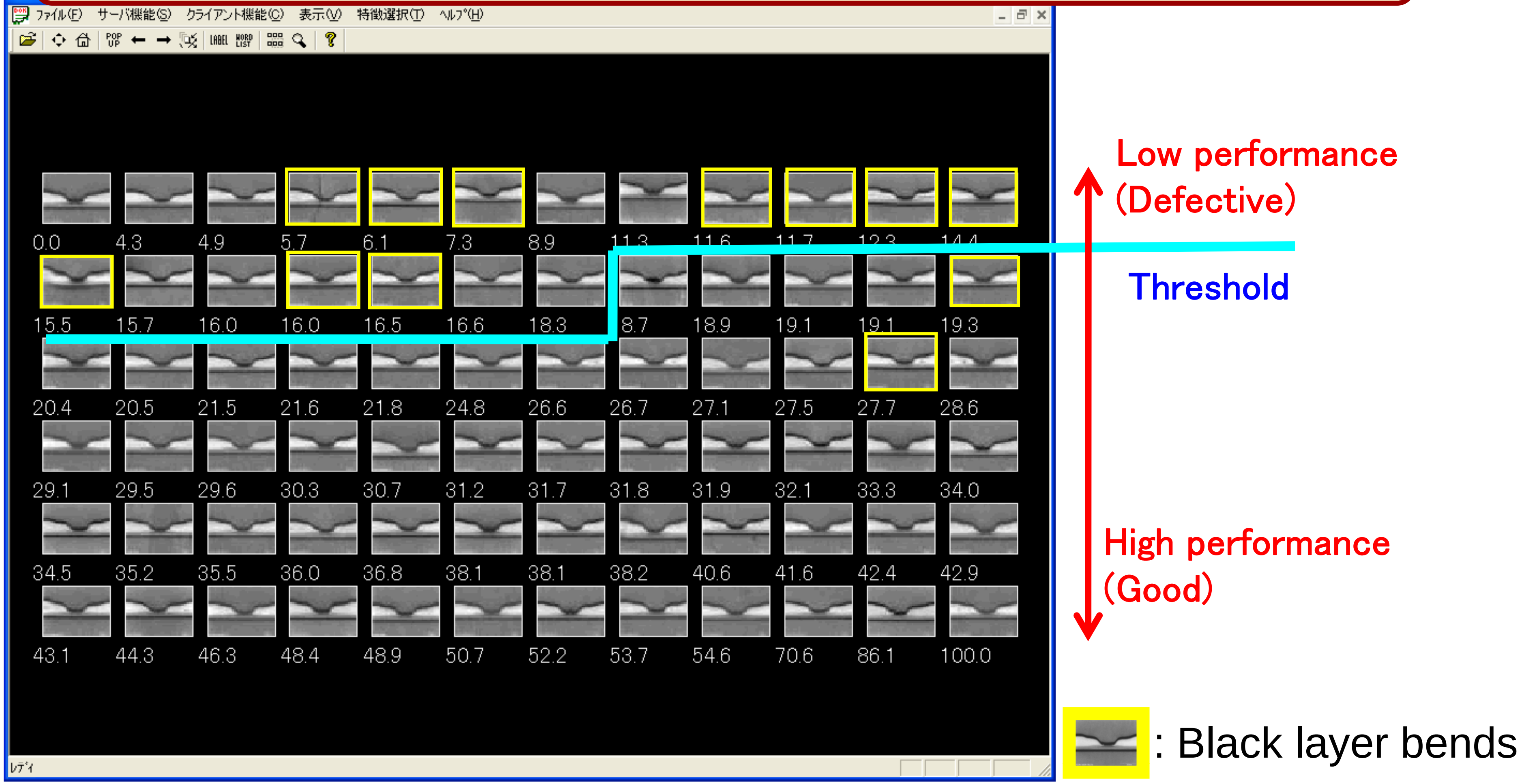
■ Demonstration

- **Arrangement of images in ascending order of performance**



(1) SEM images

Hypothesis: “Black layer bends” ⇒ ”Performance is low (Defective)”

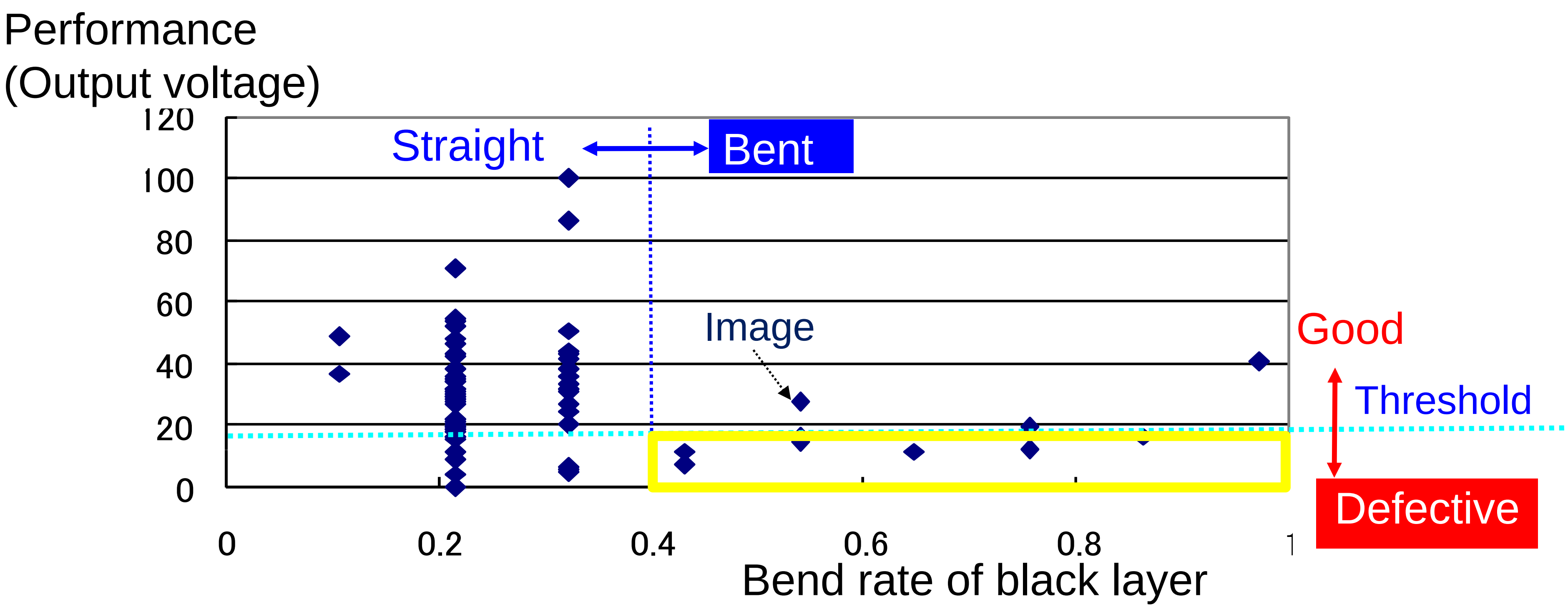


We could find that the shape of black layers affected the performance.

(1) SEM images

■ Hypothesis verification

Hypothesis: “Black layer bends” ⇒ ”Performance is low (Defective)”



(1) SEM images

Hypothesis verification

Hypothesis: “Black layer bends” ⇒ ”Performance is low (Defective)”

- **Support = 0.14, Confidence = 0.83**
- **Head design experts verified that this novel knowledge was very valuable.**

We succeeded at determining the types of visual features which affected the performance.

Definition

Association rule: F⇒M

Support

$$= \frac{\text{\# of data that satisfy both F and M}}{\text{Total \# of data}}$$

Confidence

$$= \frac{\text{\# of data that satisfy both F and M}}{\text{\# of data that satisfy F}}$$

Industrial applications

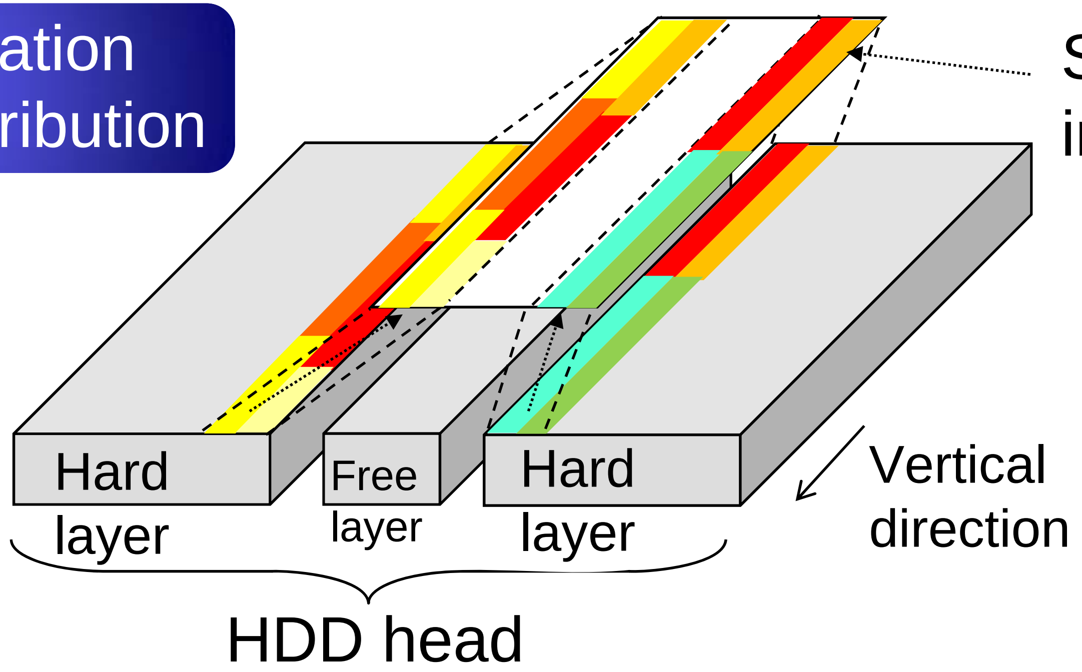
(1) Scanning electron microscope images

(2) Computer simulation images

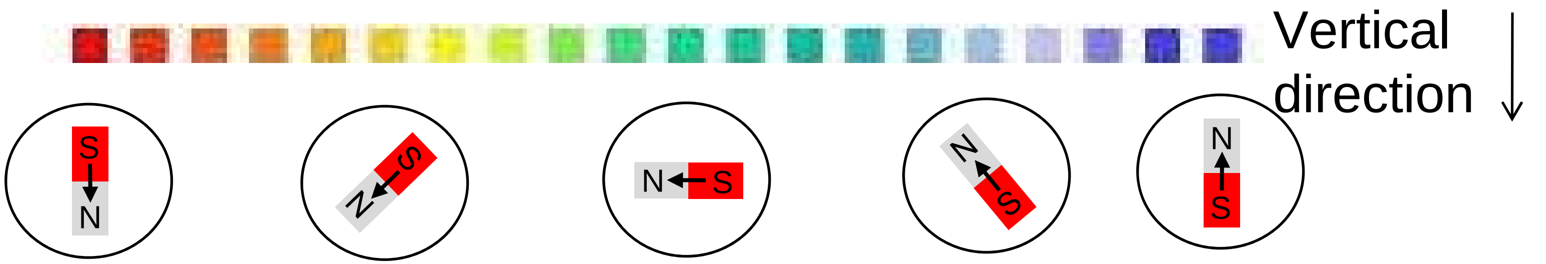
(2) Computer simulation images

Effective use of large amounts of simulation data is important.

Computer simulation of magnetic distribution

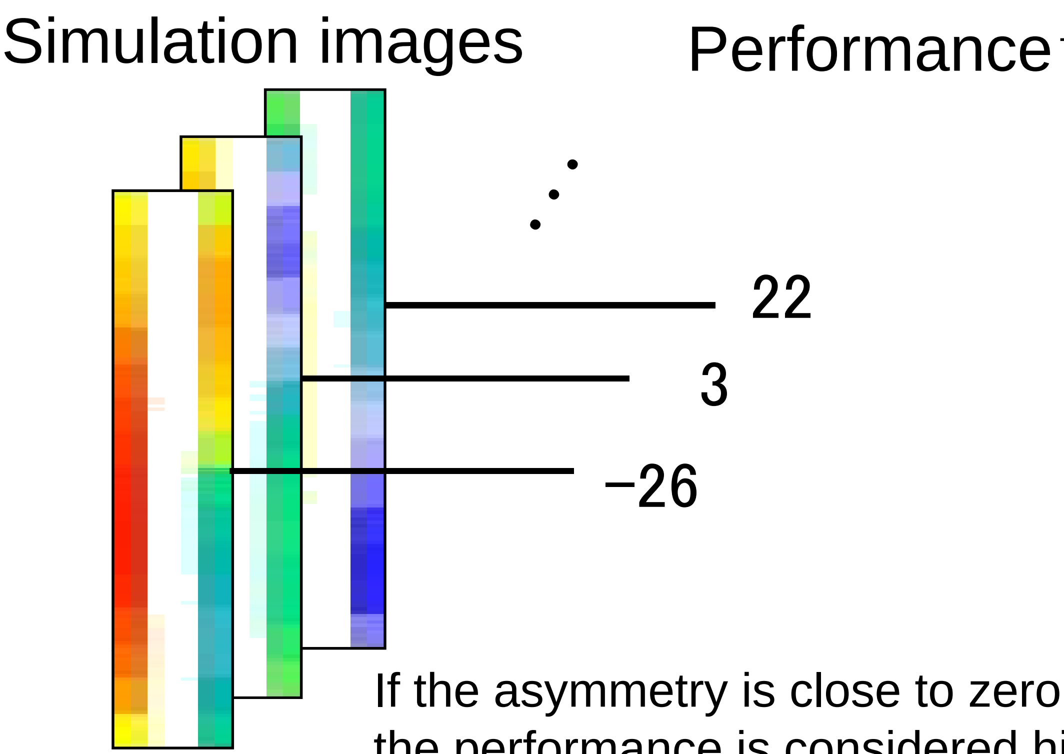


Magnetic orientation

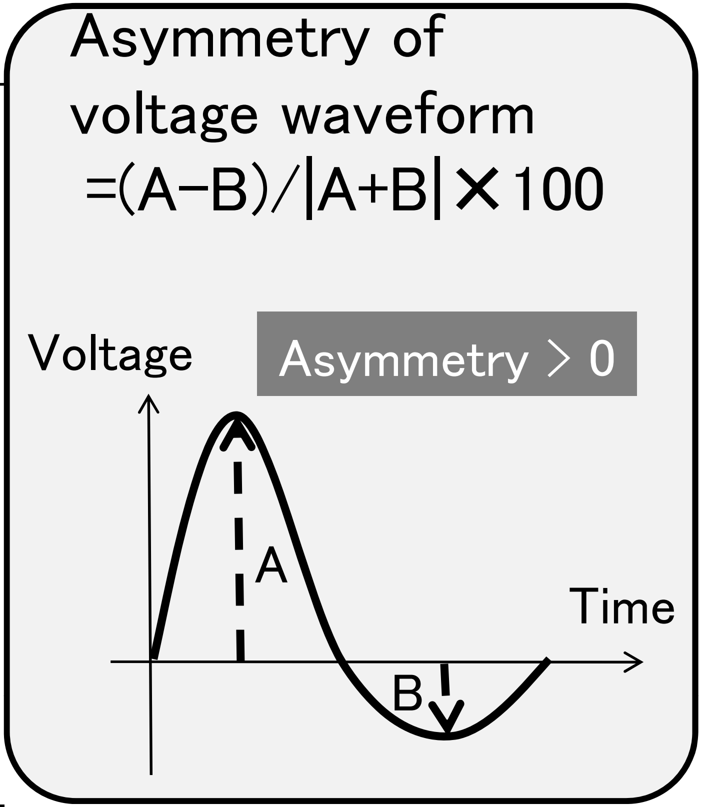


(2) Computer simulation images

- **Goal**
  - **To discover relationships between the magnetic distribution on each head and the head performance**
- **Input data: 50 images**

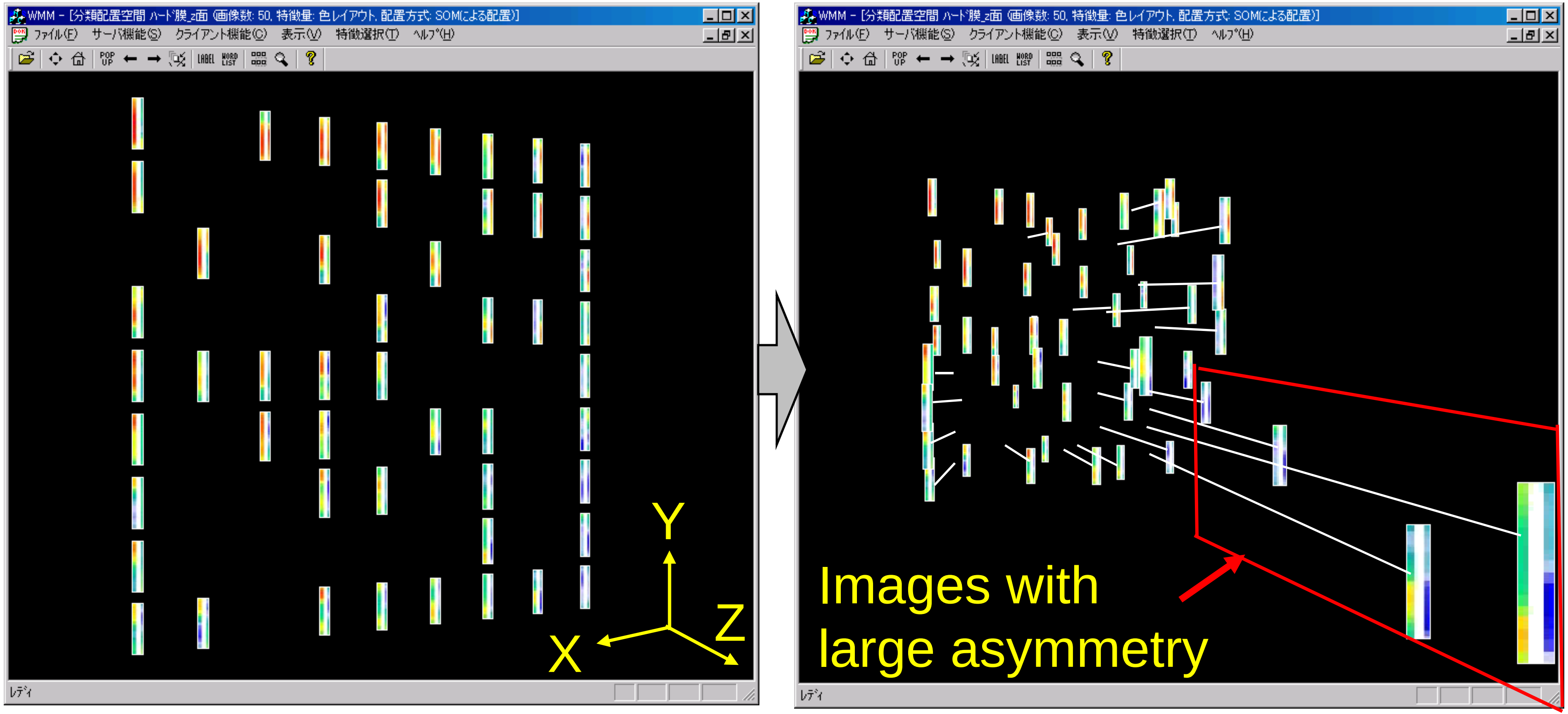


If the asymmetry is close to zero, the performance is considered high.



(2) Computer simulation images

■ Demonstration

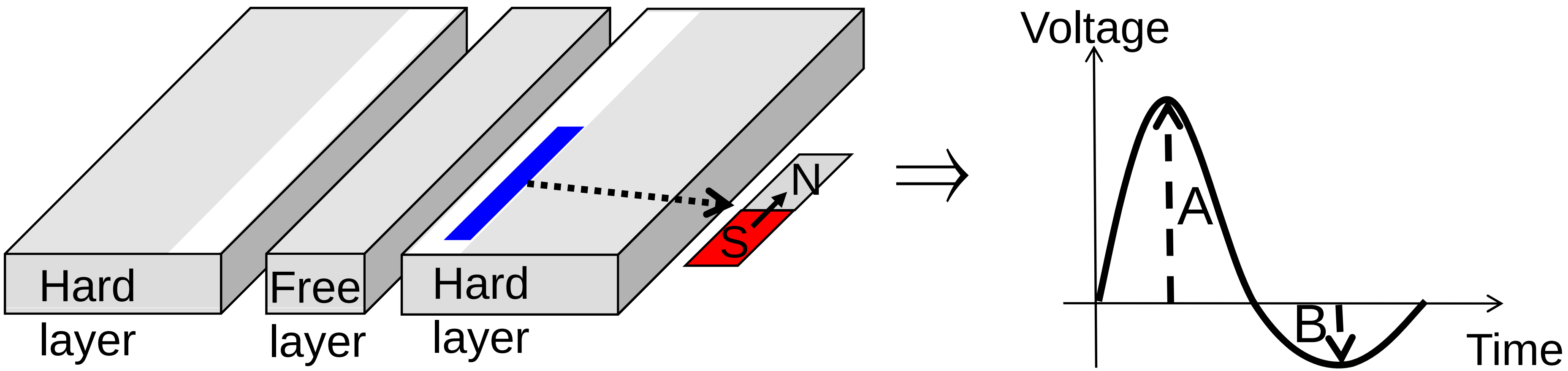


Arrangement based
on color feature

“Asymmetry” is assigned
to the depth (Z-axis)

(2) Computer simulation images

Hypothesis: “Color in the bottom right is blue” ⇒ “Asymmetry > 0”



- **Hypothesis verification**
  - **Support = 0.08, Confidence = 0.80**
  - **Head design experts verified that this novel knowledge was valuable.**

We succeeded at determining the types of visual features which affected the performance.

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Conclusions

- We have proposed an image mining system that enables users to determine the types of visual features which affect the performance by exploring images without domain heuristics.

- We applied the system to two applications in engineering design and manufacture. The results confirm that the types of visual features which affect the performance can be determined.