Overview of Second-Year Science and Mathematics Research Projects in 2025

This document presents summaries of the research projects conducted by second-year students in the Science and Mathematics Inquiry Program (Risu Tankyu) that received awards in School Year 2025.

Awarded Groups and Their Research Titles

A. Mathematical Informatics Division – Group A-22
"How Can Machines Solve Problems More Intelligently? — Exploring Contribution Calculation Methods in Adaptive Operator Selection for Mathematical Optimization"

B. Materials Chemistry Division – Group A-05
"Effects of Tail Amplitude and Shape of Cylindrical Wings on Flight Performance"

C. Life Science Division – Group B-26
"The Relationship Between Water Hardness and Hair — Fighting Hard Water! The Smooth Hair Project"

D. Humanities Division – Group C-18
"A Proposal for Enhancing Motivation for Art Appreciation Through the Provision of Background Knowledge"

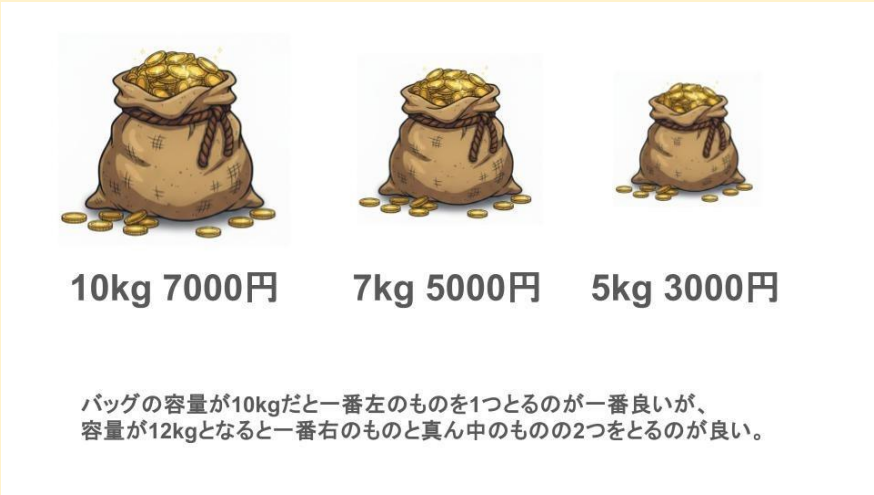
A. Mathematical Informatics Division – Group A-22

"How Can Machines Solve Problems More Intelligently? — Exploring Contribution Calculation Methods in Adaptive Operator Selection for Mathematical Optimization"

1. Background and Purpose

Mathematical optimization is a technique for finding the best possible solution under given constraints. A typical example is the knapsack problem, where one must determine how to pack items of varying weights and values into a bag with limited capacity to maximize total value.

When machines solve such problems, they improve candidate solutions step by step using various "operators." This study aims to investigate whether the quality of the final solution can be improved by devising a better method for calculating the contribution of each operator—essentially, determining which operator is most effective at a given moment.



2. Methods

・Target problem: Knapsack problem

・Operators used: 1-bit flip, mutation, crossover

・Proposed method: A new calculation approach called “special median (tentative name)”, which updates past improvement data to reflect recent performance before taking the median

・Comparison: 100 trials each using the conventional mean-based evaluation and the proposed method

・Analysis: Statistical comparison using a t-test

3. Results

As a result of the analysis, the following data were obtained.

・Solution quality: The proposed method produced significantly better solutions.

・Hit rate: The number of times the method correctly identified the best operator decreased significantly.

4. Discussion and Future Work

The “special median” improved overall solution quality. The lower hit rate is likely due to the method being designed for long-term evaluation, making short-term performance harder to capture. Future work will focus on refining evaluation criteria and testing on more complex problems.

B. Materials Chemistry Division – Group A-05

“Effects of Tail Amplitude and Shape of Cylindrical Wings on Flight Performance”

1. Motivation and Purpose

Interested in the principles of flight, the group explored whether everyday materials could be used

to create flying objects. Prior studies (Nakahara et al., 2022; Yamamoto et al., 2024) suggested that wavy tails improve flight and that air behind the wing disperses in a spiral pattern.
This study investigates how differences in tail amplitude and wave shape affect flight distance and trajectory.

2. Methods

Six cylindrical wings were made using 0.21 mm thick paper:

- Amplitudes: 1.0 cm, 2.0 cm, 3.0 cm (small, medium, large)
- Shapes: Smooth and jagged
- Other conditions:
  - Circumference: 22 cm
  - Number of waves: 3
  - Weight balance adjusted by attaching layered strips of paper to the top

Smooth

jagged

A handmade launcher was used to shoot each wing with rightward rotation. For each wing, 300 trials were conducted, measuring horizontal deviation and flight distance. Statistical analyses included:

- Within-group: One-way ANOVA and Tukey's test
- Between groups: t-test

3. Results and Discussion

Both smooth and jagged wings showed the trend: large < medium < small in flight distance.

Smooth wings showed significant differences among all amplitudes, while jagged wings showed significance only for the small amplitude.

Larger amplitudes increased Magnus force, reducing flight distance.

Smooth wings were more affected by amplitude due to smaller paper area near the body, causing stronger interaction with spiraling airflow.

For small amplitude, differences may be due to other factors.

4. Conclusion and Future Work

The jagged wing with a 1.0 cm amplitude achieved the longest and most stable flight.

Larger amplitudes increased Magnus force excessively, reducing distance.
Future studies will examine mass, thickness, center of gravity, and rotation speed.

C. Life Science Division – Group B-26

"Minimizing Hair Damage in Hard Water Regions: An Experimental Evaluation"

Experimental Overview

In this study, we investigated the effects of water hardness (soft, hard, and very hard water) on human hair and explored methods to reduce these effects.

Using human hair samples, repeated washing and drying were conducted under different water hardness conditions. In addition, experiments were performed using combinations of anionic, nonionic, and cationic surfactants, as well as citric acid. Changes in hair texture, manageability, and gloss after washing were compared and evaluated.

The results showed that washing with hard water increased roughness and stiffness, and decreased manageability and gloss of the hair. This is likely due to calcium ions (Ca^{2+}) and magnesium ions (Mg^{2+}) adhering to the hair surface and disrupting the cuticle structure.

Furthermore, anionic surfactants were found to enhance the negative effects in hard water, while nonionic surfactants helped reduce these effects. Cationic surfactants improved the overall condition of the hair. In addition, citric acid reduced the effects of hard water by suppressing the activity of metal ions.

These findings suggest that selecting appropriate washing conditions according to water hardness is important for reducing hair damage.

D. Humanities Division – Group C-18

"Enhancing Motivation for Art Appreciation Through the Provision of Background Knowledge"

Due to museum closures caused by declining visitor numbers, this study aimed to increase high school students' motivation to visit art museums.

Experts classify information extracted from artworks into:

- Concrete elements depicted
- Relationships among elements

Beginners tend to focus only on the first category. The hypothesis was that providing background knowledge would help viewers notice relational aspects, deepening appreciation.

Methods

- Conducted a survey on museum visitation frequency and reasons for not visiting

・Used the painting “The Fall of Icarus”
・Participants were divided into three groups:
    Group 1：No background information
    Group 2：Background information provided as text
    Group 3: Background information provided as illustrations
・Collected multiple-choice feedback and written impressions
・Performed text mining on written responses

Results and Discussion

Background knowledge increased motivation for art appreciation. However, considerations such as accessibility and museum environment suggest room for improvement in delivery methods.

Text mining showed increased variety and number of words related to story and interpretation, indicating deeper engagement.

Conclusion and Future Work

Providing background knowledge enhances satisfaction and increases willingness to visit museums. Future research will focus on tailoring methods to individuals who rarely visit museums.