Analysis of Weather Information and Road Surface Images for Snow Removal Dispatch Prediction

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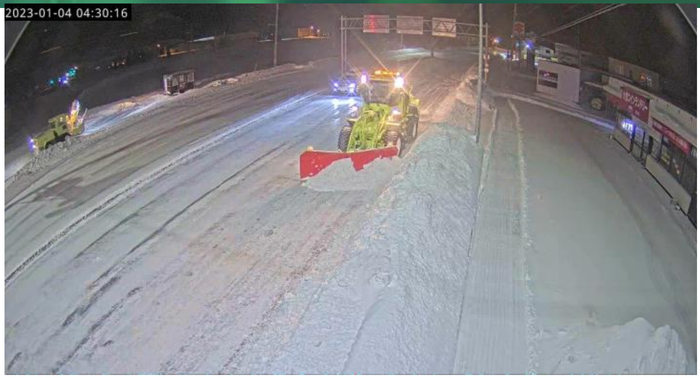
- Education
  - second-year master’s student at the Graduate School of Information Science and Technology, Hokkaido University, Japan.

- Research Area
  - image recognition, system development, snow removal dispatch prediction

Background



- Road snow removal operations
  - Essential for maintaining winter road traffic
    - The snow removal budget in Sapporo City, Hokkaido exceeds 1.2 billion EUR.[1]
  - Burdens due to shortage of workers and aging workforce
    - Addressing the shortage of workers with single-operator snow removal vehicles
    - Ensuring safety in snow removal operations with biometric sensors
  - Burden exists within snow removal dispatch decisions.

- Methods for snow removal dispatch decisions
  - Manager makes first decision based on weather information at 16:00.
  - Manager makes final decision based on snow patrol at late-night.

[1] The actual expenditure on snow measures-City of Sapporo, https://www.city.sapporo.jp/kensetsu/yuki/library/budget.html, (retrieved: 2, 2024)

Background

- Challenges in snow removal dispatch decisions
  - ①**Manager makes decisions alone.**
    - To streamline collecting information, support is necessary.
  - ②**Even experienced managers find it difficult to make decisions at 16:00.**
    - To make it easier for anyone, high-precision prediction function is necessary.
  - ③**Snow patrols are time-consuming and dangerous.**
    - To eliminate direct patrols, remote checking of snow conditions is necessary.
  - ④**Workers don't know whether snow removal will take place until late-night communication.**
    - To enable workers to understand dispatch without waiting for late-night communication, sharing of information is necessary.

⇒ <u>Collection and visualization of on-site data, as well as high-precision dispatch prediction function are necessary.</u>

Related Research

- Data visualization and analytical inference are effective.
  - Visual Analytics[1]
    - Visualizing and analyzing complex data supports decision-making.

➡ <u>Visualizing snow-related data and predicting</u>

- Remote presence using cameras improves operational efficiency.
  - Operational efficiency through remote presence[2]
    - Remote presence using cameras streamlines the need to be physically present.

➡ <u>Applying remote presence to snow patrols</u>

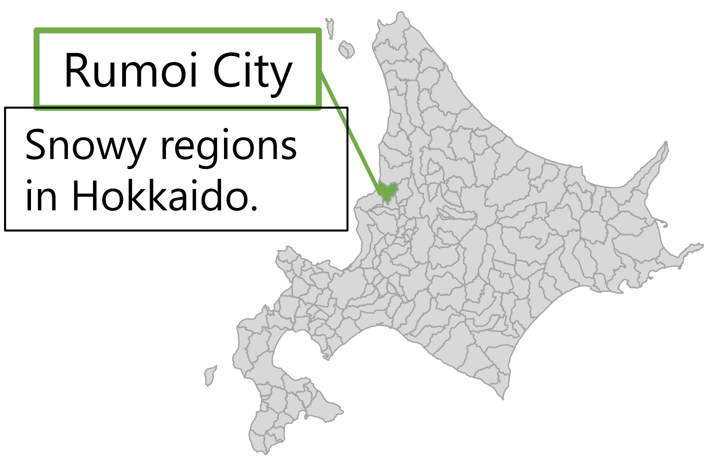
- Weather information as a factor in snow removal dispatch
  - Optimizing snow removal operations based on snowfall predictions[3]
    - Predicting snowfall based on meteorological satellite and radar observation data supports decision-making in snow removal.

➡ <u>Using as input for dispatch prediction</u>

[1] James J. Thomas and Kristin A. Cook : Illuminating the Path: The Research and Development Agenda for Visual Analytics, (2005)
[2]Ryutarou Kimura, Keidai Suda, Hidetoshi Turuta: Examples of remote field supervision, Proceedings of the 65th Hokkaido Development Technology Conference (FY 2021), (2021)
[3]Tetsuro Akimoto, Michihiro Teshiba, Ayano Ueki: Applications of novel weather information: optimization for deployment of snow removal groups, Artificial Intelligence and Data Science, 3, J2, 215-222, (2022)

Research Objective

- Development of system to support snow removal dispatch decisions using collected data
  - Implementing functions for data collection and utilization
    - Collection and visualization of snow removal site data
    - Predicting snow removal dispatch using collected data
  - Verifying the effectiveness of system in practical operations
    - Implemented at Horiguchi Construction Co., Ltd.



Targeted Snow Removal Dispatches

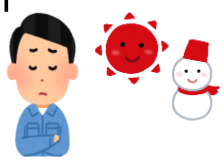
- The target area for snow removal dispatch
  - The urban area of Rumoi City, Hokkaido
    - Within approximately 12 kilometers of national road
- The criteria for dispatch
  - Carried out when the snow depth confirmed during snow patrol exceeds 10 cm.
- The average frequency per year from 2018 to 2020
  - Snow patrols: 105 times
  - Late-night snow removal dispatches: 44 times

Support via System Utilization

- Traditional methods for snow removal dispatch decisions

16:00 → 0:00 → 1:00 → 2:00

①First manager's decision



②Snow patrol

③Final manager's decision

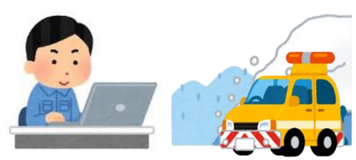
- New methods for snow removal dispatch decisions

16:00 → 0:00 → 1:00 → 2:00

Workers can check data and prepare for dispatch.

①First manager's decision based on **dispatch prediction**

②**Check the data** and snow patrol **as needed**



③ Final manager's decision

Reduction of manager burden

Streamlining snow patrols

Reduction of burden

Data Collection

- Collecting data necessary for snow removal dispatch decisions
- Details of the data and collection methods

	Data	Details	Frequency	Collection methods
1	Fixed-point camera images	From network cameras installed at 10 locations in Rumoi City	Every few seconds	Via API from network
2	Weather information	Current and forecasted information for each location	Every hour	Via API from WeatherNews Inc.
3	Snow depth	From snow depth gauges installed at 2 locations 10km away from city	Every 10 minutes	Via API from network
4	Dispatch history	Manager's decisions and dispatch records		

Data Collection

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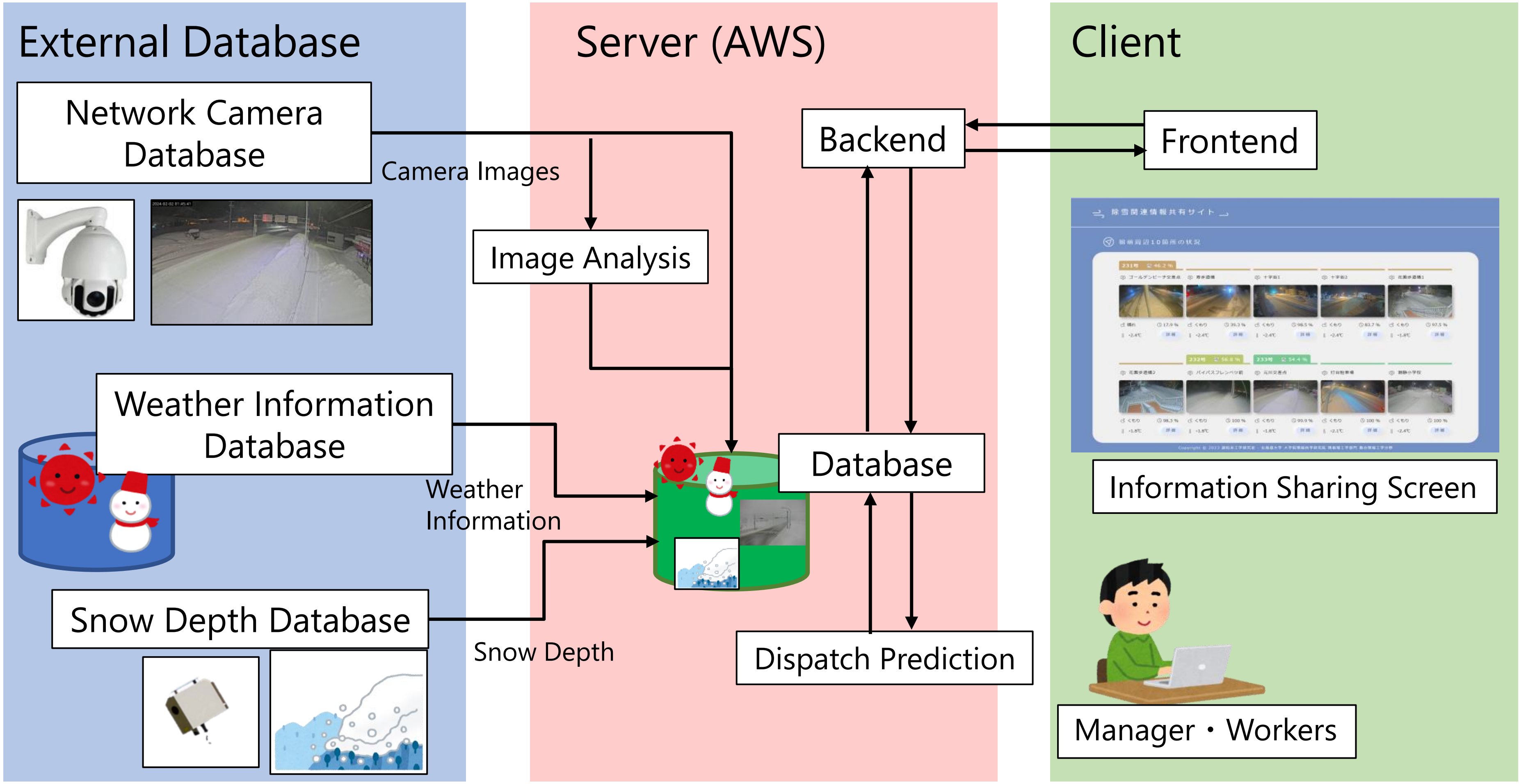
4	Dispatch history			

Issue with snow depth gauges

- Specific measurement value from a single point
- High equipment and installation costs

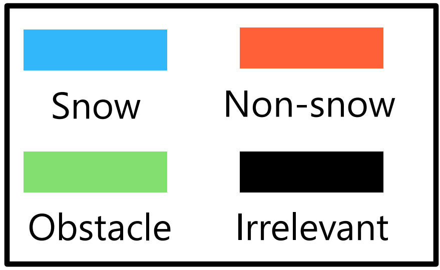
Dispatch Decision Support System

- The server collects data from the external database.
- The server responds to the client requests.



Quantification of Snowfall Conditions

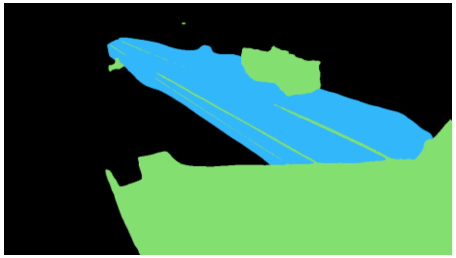
- Objective
  - Capturing changes in snow accumulation
- Estimation of snow coverage ratio
  - What is snow coverage ratio?
    - Quantifying proportion of road surface covered by snow within entire road area
  - Application of semantic segmentation
    - Annotation of 752 images from all 8 locations
    - Utilizing the pre-trained model Unet++
    - IoU score on the test data : 0.951



Input image

Application of the model

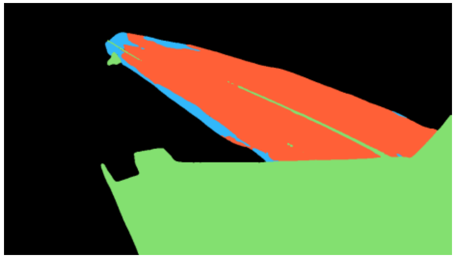
Snow coverage ratio 100%



Input image

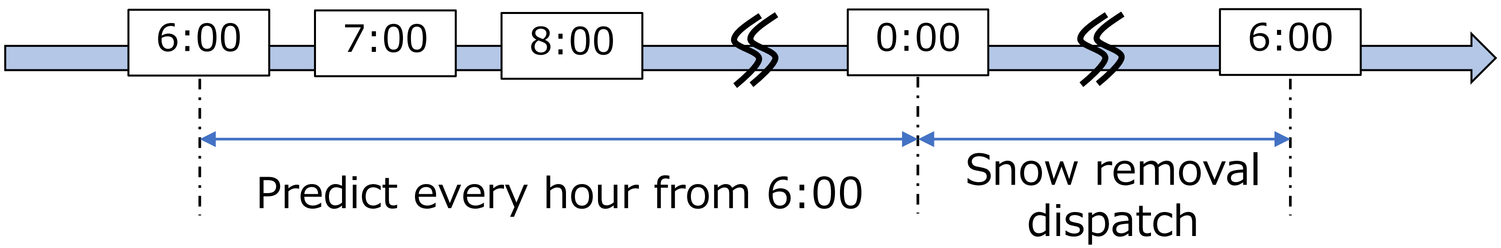
Application of the model

Snow coverage ratio 5%

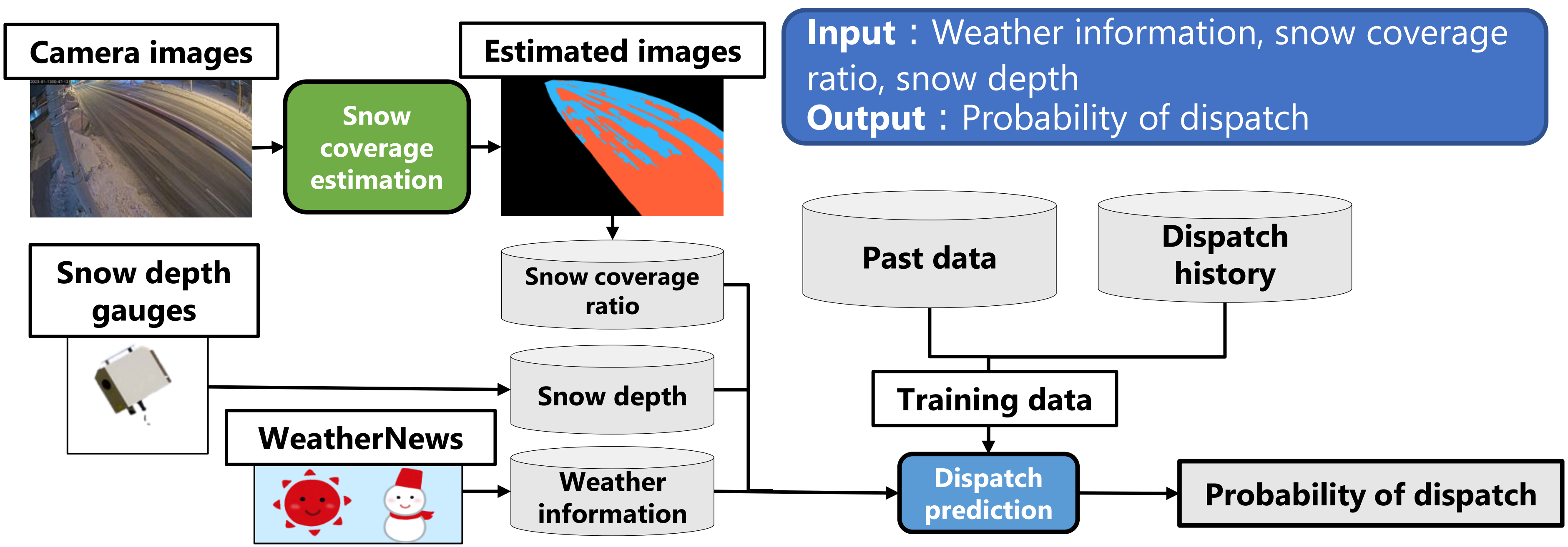


Snow Removal Dispatch Prediction

- What is a snow removal dispatch prediction?



- Data for prediction
  - Weather information, snow coverage ratio, snow depth
- Prediction model: logistic regression



Information Sharing Screen

- Visualizing the collected data from all locations collectively

Expt.1 Accuracy Investigation of Prediction

- Objective
  - Predicting dispatches from collected data, confirming the system's usability based on prediction accuracy
- Dataset
  - Period
    - December 24, 2022, to February 28, 2023 (67 days)
    - Utilizing the 63 days excluding missing data
  - Contents
    - Weather information, snow coverage ratio, snow depth
      - Collected data observed hourly
    - Forecasted weather information
      - Forecasted for 20:00, 0:00, and 4:00 at 5:00
    - Dispatch history
      - Presence or absence of snow removal dispatch from 0:00 to 6:00
- Method
  - Making Predictions hourly from 6:00 to 0:00
  - Comparing between predicted results and manager’s decisions at 16:00

Expt.1 Accuracy Investigation of Prediction

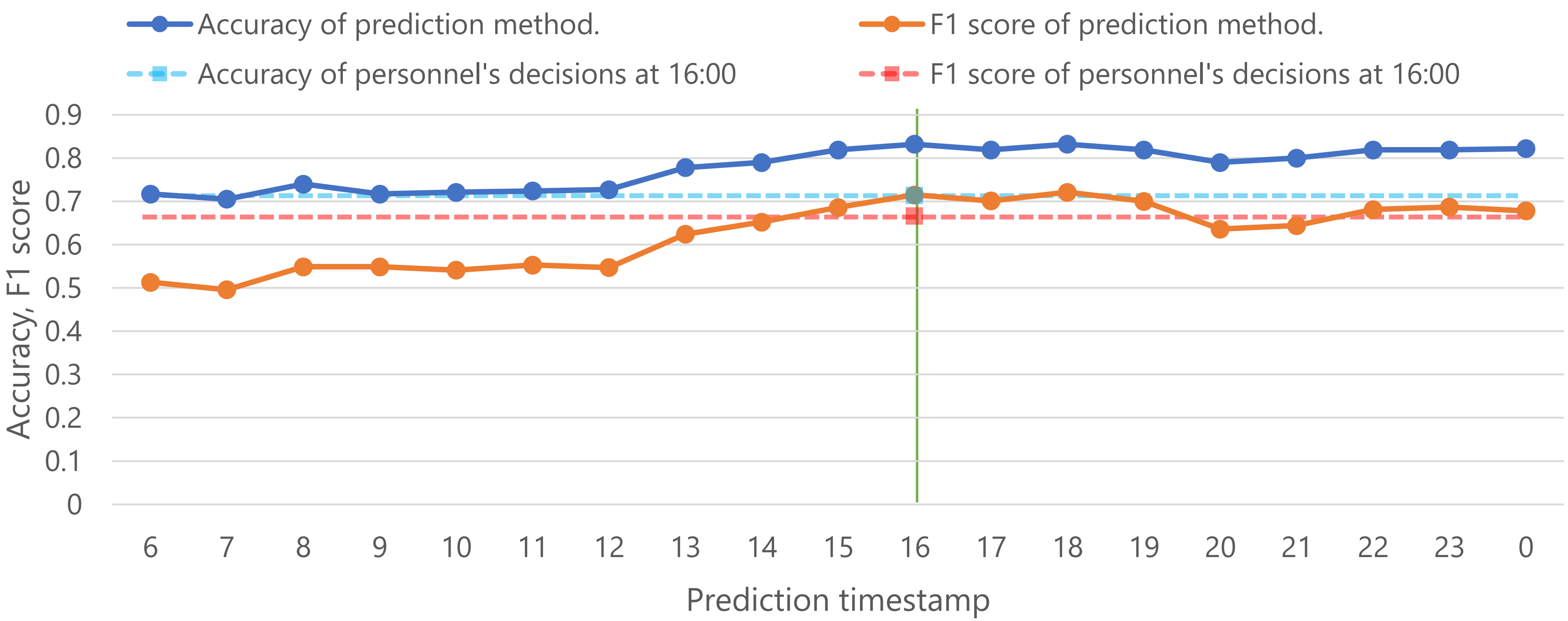
- Input features for prediction
  - Determining features based on the results of preliminary experiments

Prediction timestamp	Input features		
	Real-time observational data	Forecasted data	Past data
From 6:00 to 16:00	Snow coverage ratio, Snow depth, Temperature	Wind speed at 20:00 and 0:00	None
From 17:00 to 19:00	Snow coverage ratio, Snow depth, Temperature	Wind speed at 20:00 and 0:00	Temperature at 16:00
From 20:00 to 23:00	Snow coverage ratio, Snow depth, Temperature, Wind speed	Wind speed at 0:00	Temperature at 16:00
0:00	Snow coverage ratio, Snow depth, Temperature, Wind speed	None	Temperature at 16:00

- Creation of the dataset
  - Dividing the number of locations and the presence or absence of dispatch into 5 partitions.
  - Setting a seed value at dividing and preparing 5 datasets
- Evaluation metrics
  - Accuracy, F1 score.
    - Using the average values of 5 datasets.

Expt.1 Accuracy Investigation of Prediction

- Comparison results between predicted results and manager’s decisions at 16:00



- Accuracy increases from 6:00 to 16:00, maintains high accuracy surpassing the manager's decisions after 16:00.
- although the learning process utilized forecasted weather information at 5:00, in actual use, it is updated hourly, which could further improve the accuracy.

➡ <u>Effective for the system</u>

Expt.2 Validation of System Effectiveness

- Objective
  - Confirming whether the system effectively addresses the challenges of snow removal dispatches
- Utilization of the system
  - Duration
    - December 27, 2023, to January 29, 2024.
- Method
  - Interview survey with 1 manager responsible for dispatch decisions
  - Questionnaire survey with 5 snow removal workers

Expt.2 Validation of System Effectiveness

- Interview survey
  - Regarding dispatch decisions
    - **Q1: What is the traditional method for making decision?**
    - A1: At 16:00, I check the snowfall condition and weather forecast, and make decisions based on my experience.
    - **Q2: What is the method using the system?**
    - A2: I make quick and easy decisions by checking the data.
    - **Q3: Does it help reduce the burdens?**
    - A3: High-precision predictions reduce the burdens of information gathering and alleviate the sense of responsibility when decisions are reversed.
  - Regarding snow patrols
    - **Q1: What is the traditional method for snow patrols?**
    - A1: I conduct snow patrols even with a small amount of snowfall, and it takes more than an hour to complete the patrols.
    - **Q2: What is the method using the system?**
    - A2: I check the data before the patrols and adjust our approach based on whether to focus on specific locations for patrols or not to conduct.
    - **Q3: Does it help streamline snow patrols?**
    - A3: It halves the total time required for traditional method over the entire season.
- Conclusion
  - The system reduces the burden of dispatch decisions and streamlines snow patrols.

Expt.2 Validation of System Effectiveness

- Questionnaire survey
  - **Q1: Are you using the system?**
  - "Yes" from 2 respondents, "No" from 3 respondents.
      - Introduced during the busy winter season, and thus not yet fully implemented.
      - The unused workers were encouraged to use it and then provide feedback.
  - **Q2: Could you imagine whether there will be snow removal dispatch or not before communicating at late-night?**
  - "Yes" from 5 respondents
  - **Q3: Did imagining make it easier to prepare for dispatch and feel more relaxed?**
  - "Yes" from 4 respondents, "No" from 1 respondents.
    - Specific examples of burden reduction
      - Adjusting sleep time by preparing in advance
      - Reducing family stress by decreasing late-night calls
- Conclusion
  - The system reduce the burden of late-night dispatch for workers.

Conclusion

- We develop a system to support snow removal dispatch decisions using collected data.
  - Collecting camera images, weather information, and snow depth
  - Implementing data visualization and snow removal dispatch prediction
- The system predicts dispatches with high accuracy, close to the managers' decision.
  - As the dispatch time approaches, it becomes possible to predict with high accuracy.
- The effectiveness of the system was validated through interview and questionnaire surveys.
  - Effective in addressing challenges in snow removal dispatches.