COVID-19 detection from thermal image and tabular medical data utilizing multi-modal machine learning

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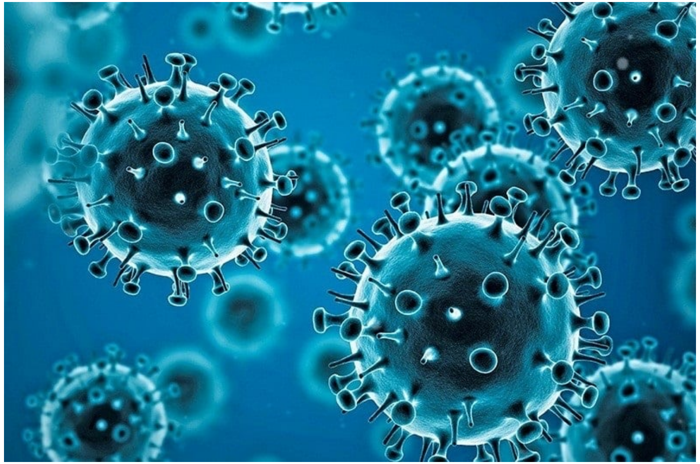
COVID-19

- A disease caused by the SARS-CoV-2 virus and can lead to severe respiratory syndromes
- It has caused a global pandemic
- The standard method for COVID-19 detection is the PCR-based DNA test
- The test requires analysis of respiratory specimens



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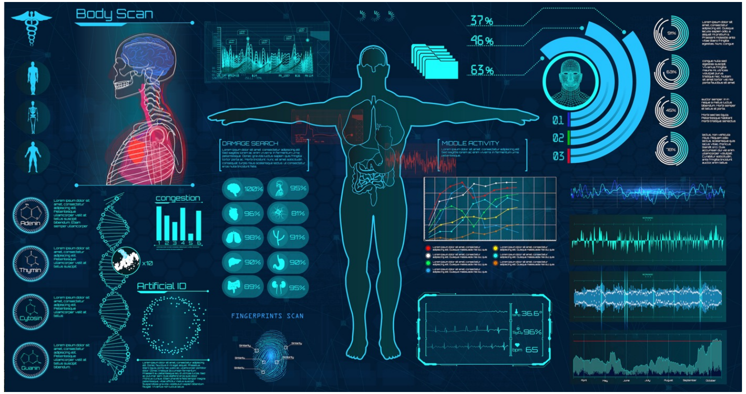
Different Data for COVID-19 detection

- Machine learning and deep learning techniques are used to detect COVID-19
- Utilizing textual, imaging, categorical, and numerical medical data
- Researchers have specifically explored medical imaging, most notably X-ray
- Chest CT and lung-ultrasound have also been investigated



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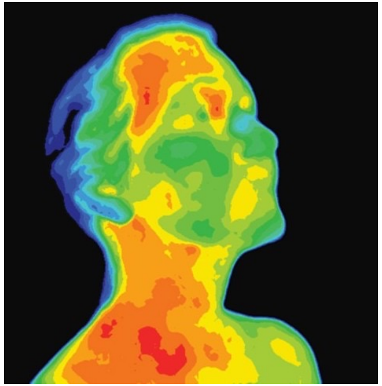
Thermal Image for COVID-19 detection

- Thermal imaging captures infrared light emitted by warm surfaces
- It detects temperature variations across different body areas
- Thermal imaging is non-invasive, contactless, and commonly used in machine learning for detection tasks
- It can be useful for medical diagnosis, including COVID-19 detection
- It can provide remote, low-cost, and contactless solutions if performance is satisfactory



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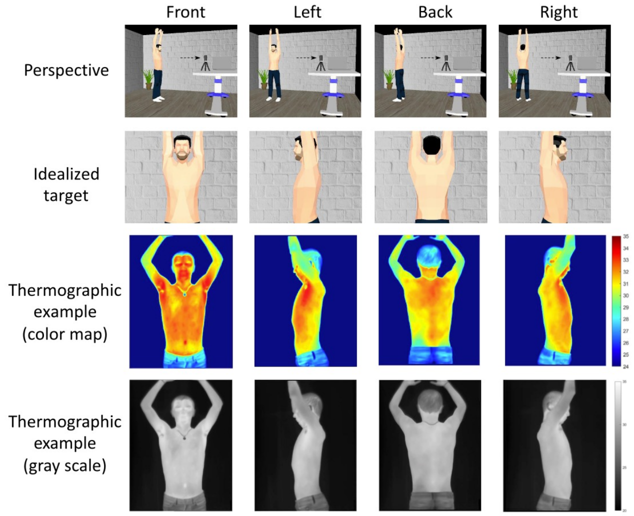
Thermal Image Covid-19 Dataset

- "Upper body thermal images and associated clinical data from a pilot cohort study of COVID-19" (version 1.1)
- 251 subjects, with 192 negative and 59 positive COVID-19 cases
- Thermal videos were recorded from four positions: front, back, left, and right for each subject
- Includes extracted signal moment, signal texture, and shape moment features in tabular format from the thermal video
- It also contains other medical information about the subjects along with their COVID-19 results



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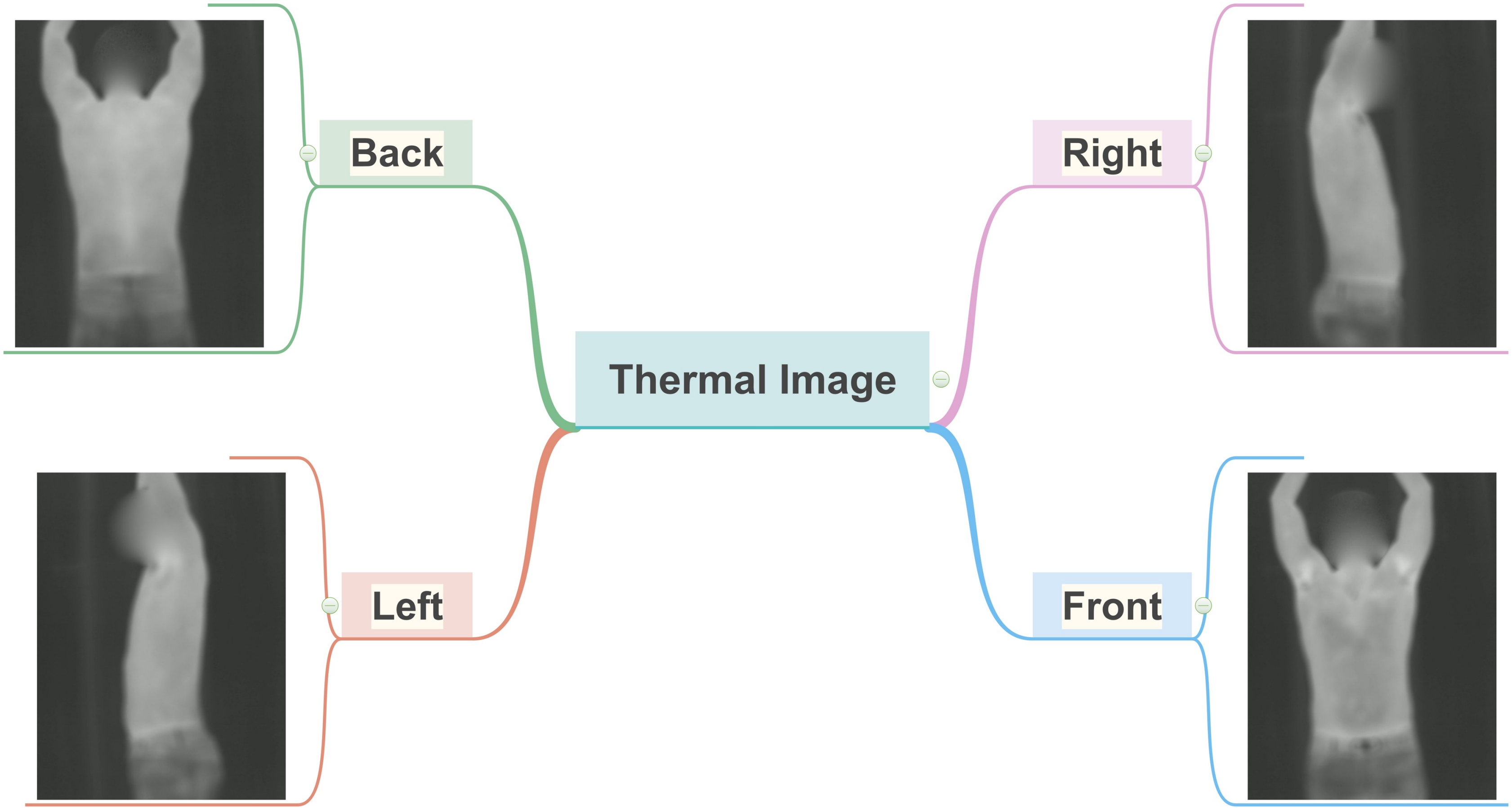
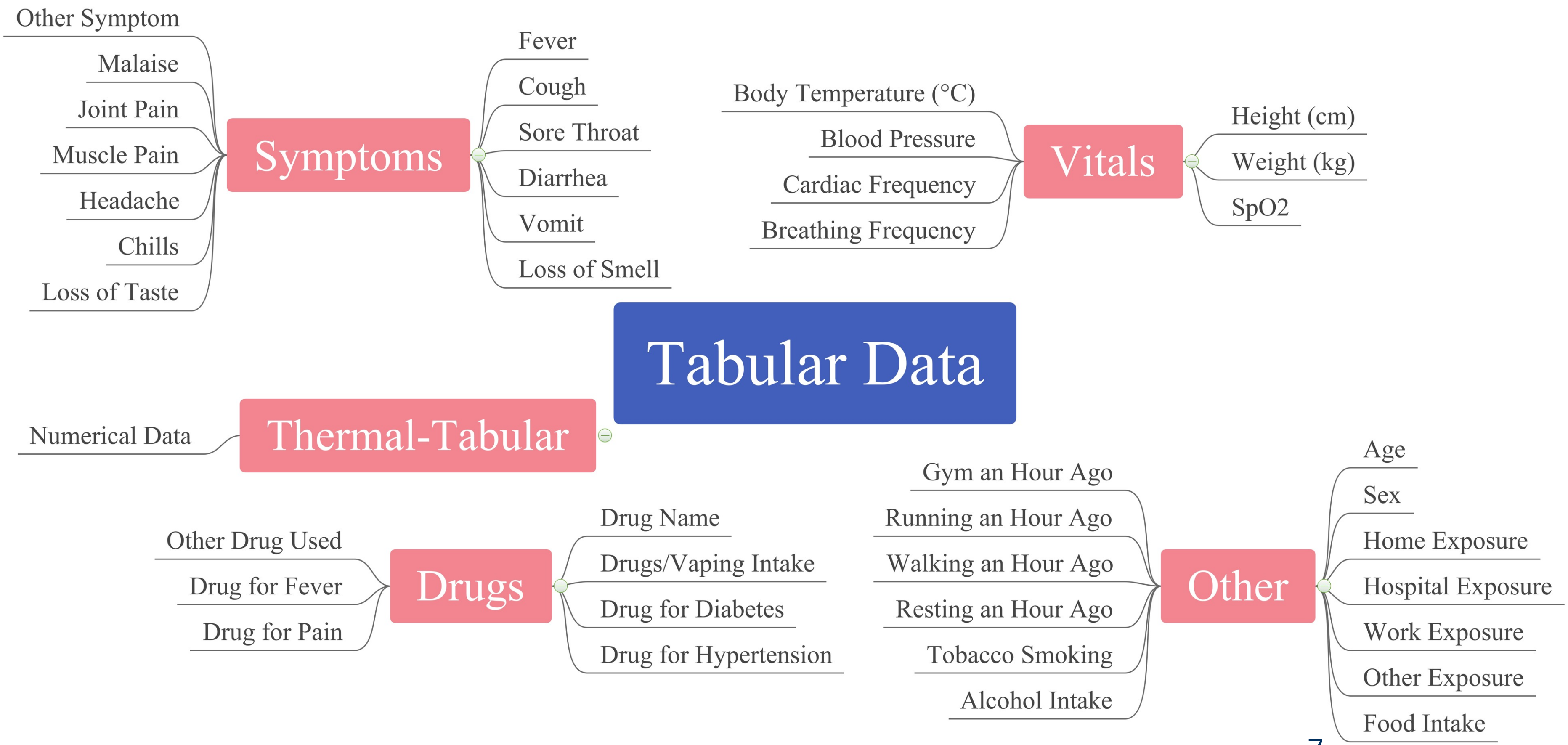
Multi-Modal Data



Multi-Modal Data



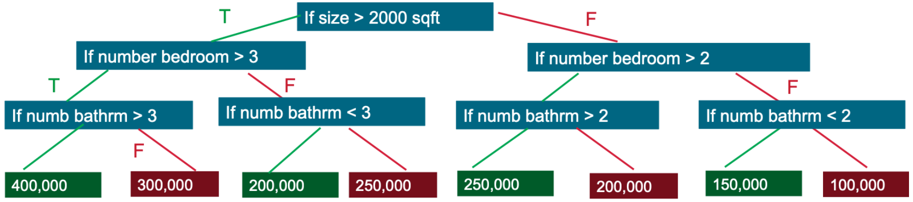
Random forests & XGBoost (Extreme Gradient Boosting)

Decision trees

- ❑ Predict label by evaluating if-then-else questions
- ❑ Estimate minimum questions for correct decision probability

Gradient boosting

- ❑ Improves weak model by combining with other weak models using a gradient descent algorithm
- ❑Sets targeted outcomes based on gradient of error



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Random forest

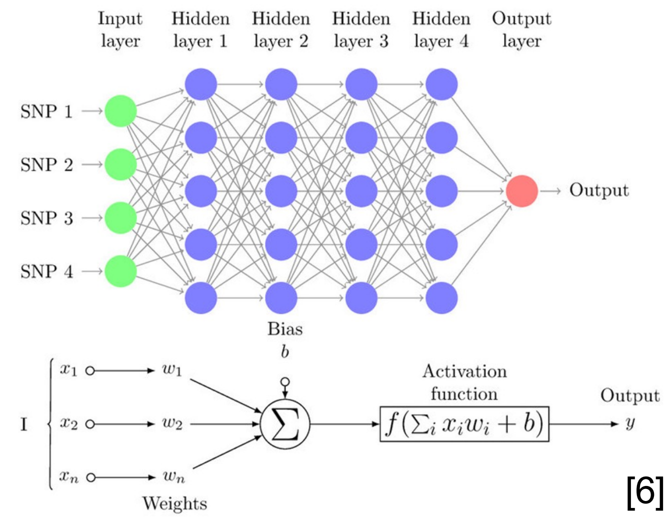
- ❑ Builds decision trees in parallel
- ❑ Final prediction is an average of all tree predictions

XGBoost

- ❑ Scalable and highly accurate implementation of gradient boosting

MLP (Multilayer Perceptron)

- Deep neural network with multiple layers of interconnected nodes called neurons
- Can learn complex relationships between inputs and outputs, making them useful for tasks like classification and regression
- MLPs use backpropagation to adjust weights based on prediction errors, improving performance over time



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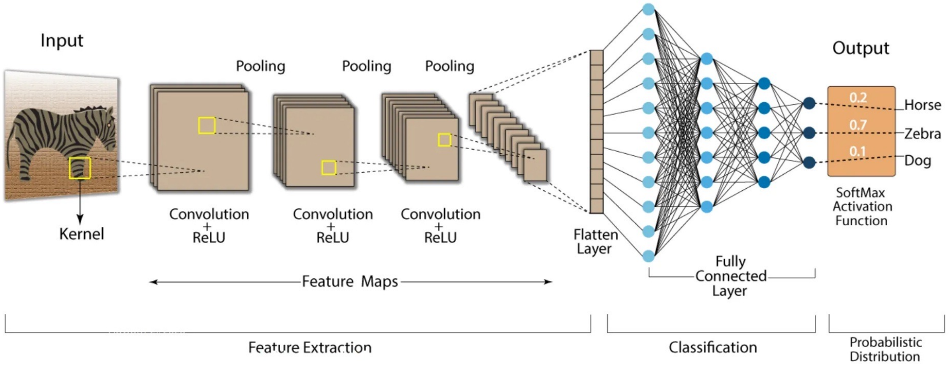
CNN (Convolutional Neural Network)

- Particularly useful for tasks involving spatial data, such as images
- Utilize convolutional layers that perform operations to capture spatial patterns in the data
- The convolutional layers apply filters to identify features in different spatial locations of the input data



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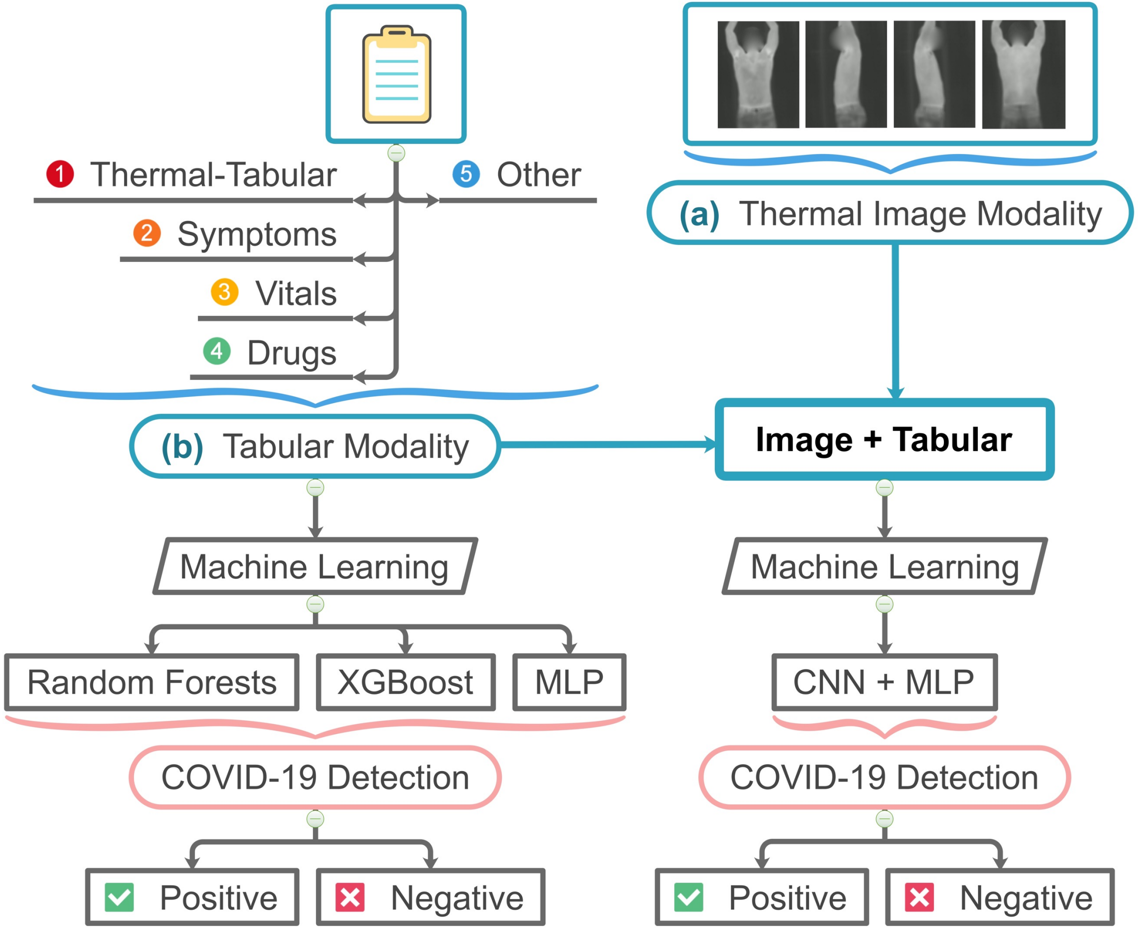
Our Multi-Modal Approach



Experimental Setup

Dataset Split

- |**Training**|**Validation**|**Test**| :
  |**80%**|**10%**|**10%**| of total data
- Same COVID-19 positive-negative ratio in all splits

Experiments

- Thirty-one experiments with different combinations of five Tabular data modalities

Reproducibility

- Specific seed values used for data splits and trials

Model Fine-tuning using validation data

- Grid search for random forests and XGBoost to find best-tuned model
- 100 Hyperparameter trials to obtain best-tuned models for MLP and CNN+MLP

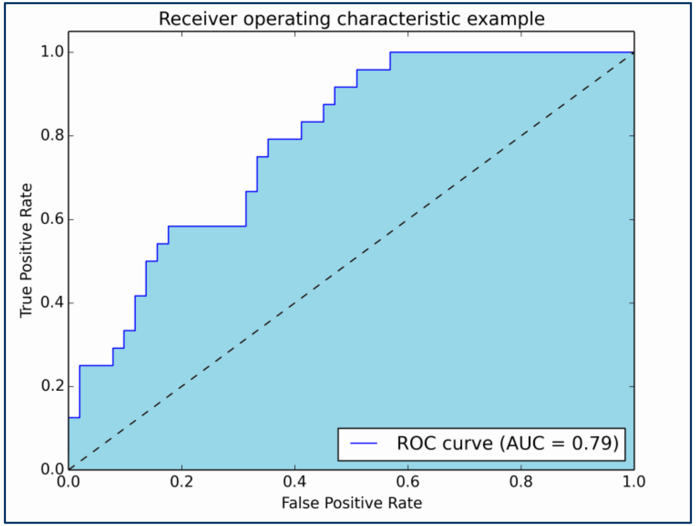
Leave-one-positive-instance-out Cross-validation

- Combined training and validation data
- Hyperparameter values from best-tuned model
- Average evaluation scores for all folds

Testing

- Best-tuned model tested using **test data**

Evaluation Metrics : AUROC & AUPRC



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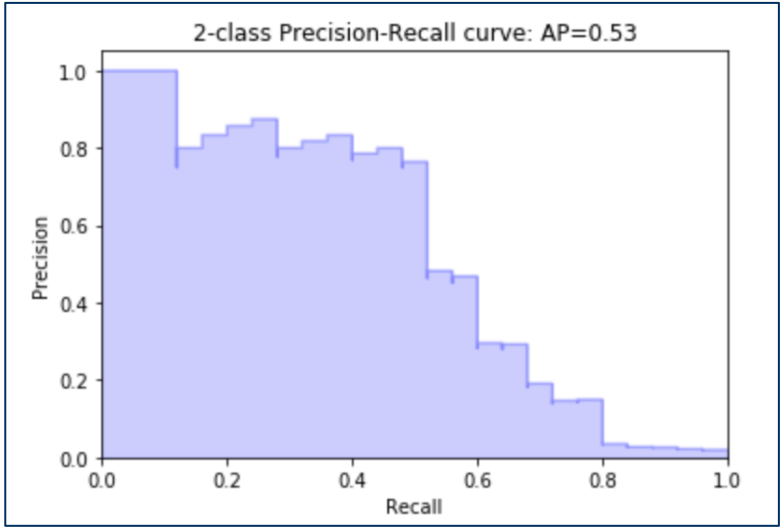

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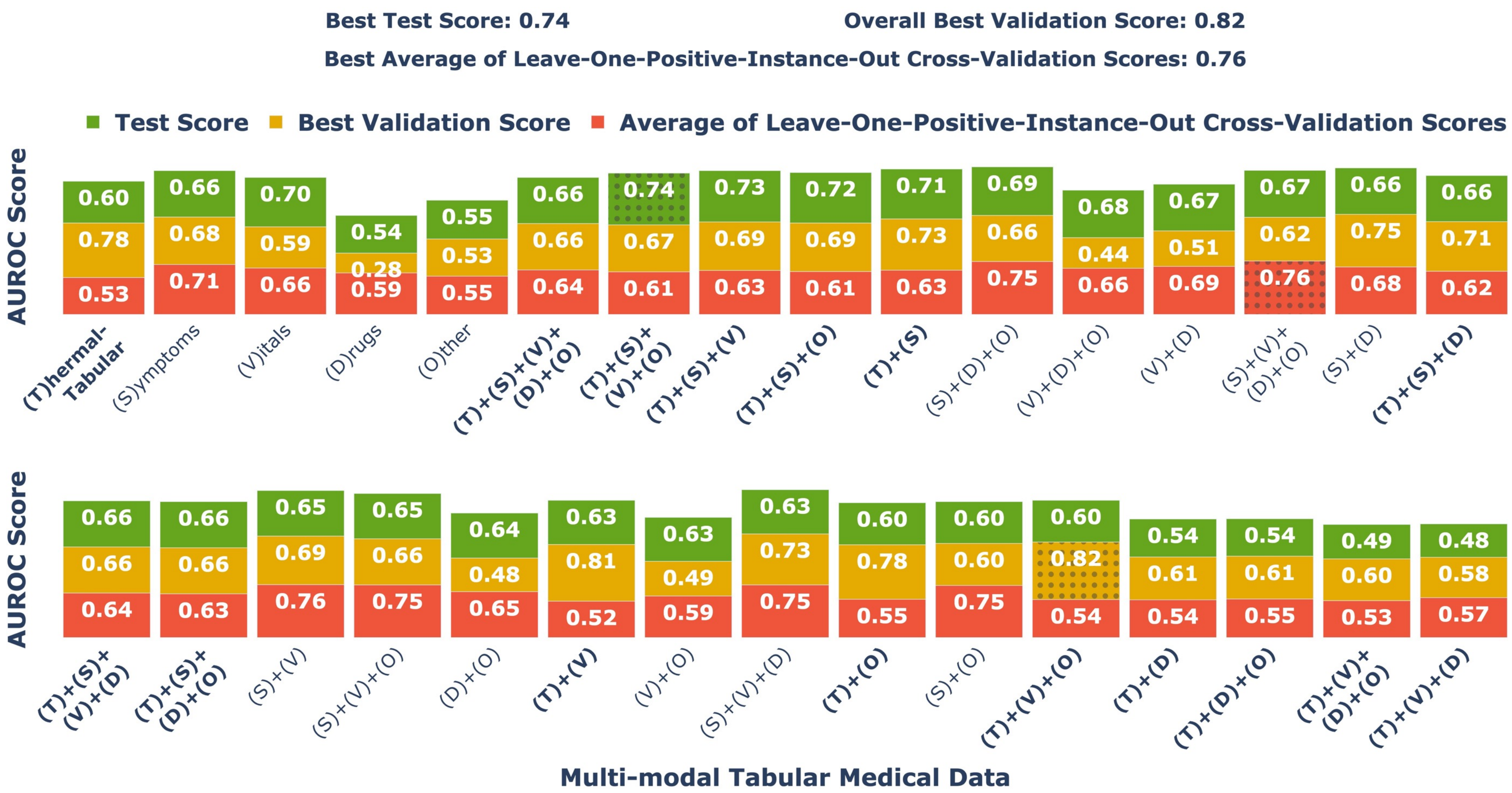
Area Under the Receiver Operating Characteristics (AUROC or AUC)

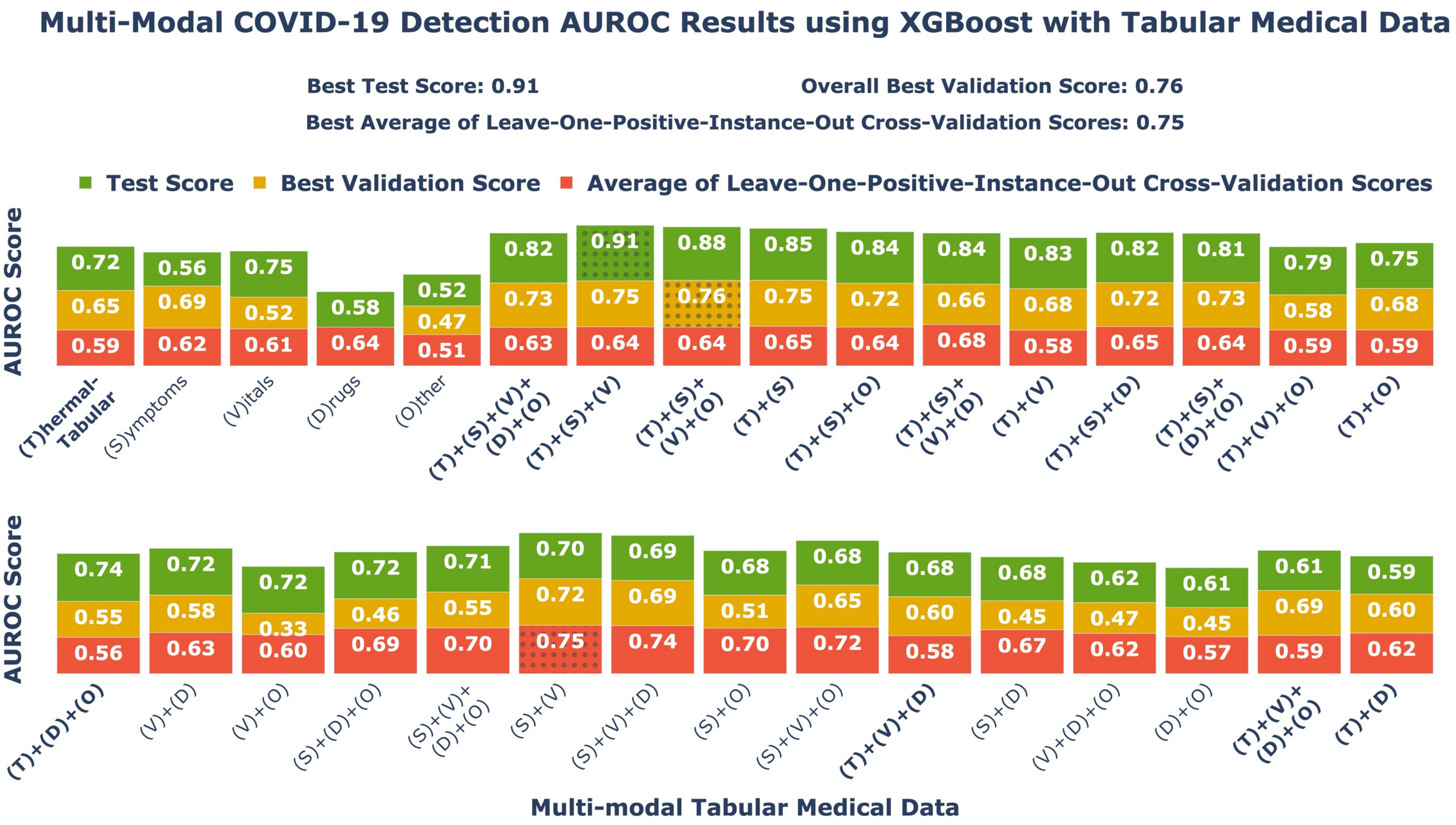
- Probability with which the classifier will assign a larger score to the positive than to the negative data point

Area Under the Precision-Recall Curve (AUPRC or AP)

- Average of precision across all recall values

Multi-Modal COVID-19 Detection AUROC Results using Random Forests with Tabular Medical Data





Multi-Modal COVID-19 Detection AUROC Results using XGBoost with Tabular Medical Data
Best Test Score: 0.91
Overall Best Validation Score: 0.76
Best Average of Leave-One-Positive-Instance-Out Cross-Validation Scores: 0.75
Test Score
Best Validation Score
Average of Leave-One-Positive-Instance-Out Cross-Validation Scores
AUROC Score
(T)hermal-Tabular
(S)ymptoms
(V)itals
(D)rugs
(O)ther
(T)+(S)+(V)+(D)+(O)
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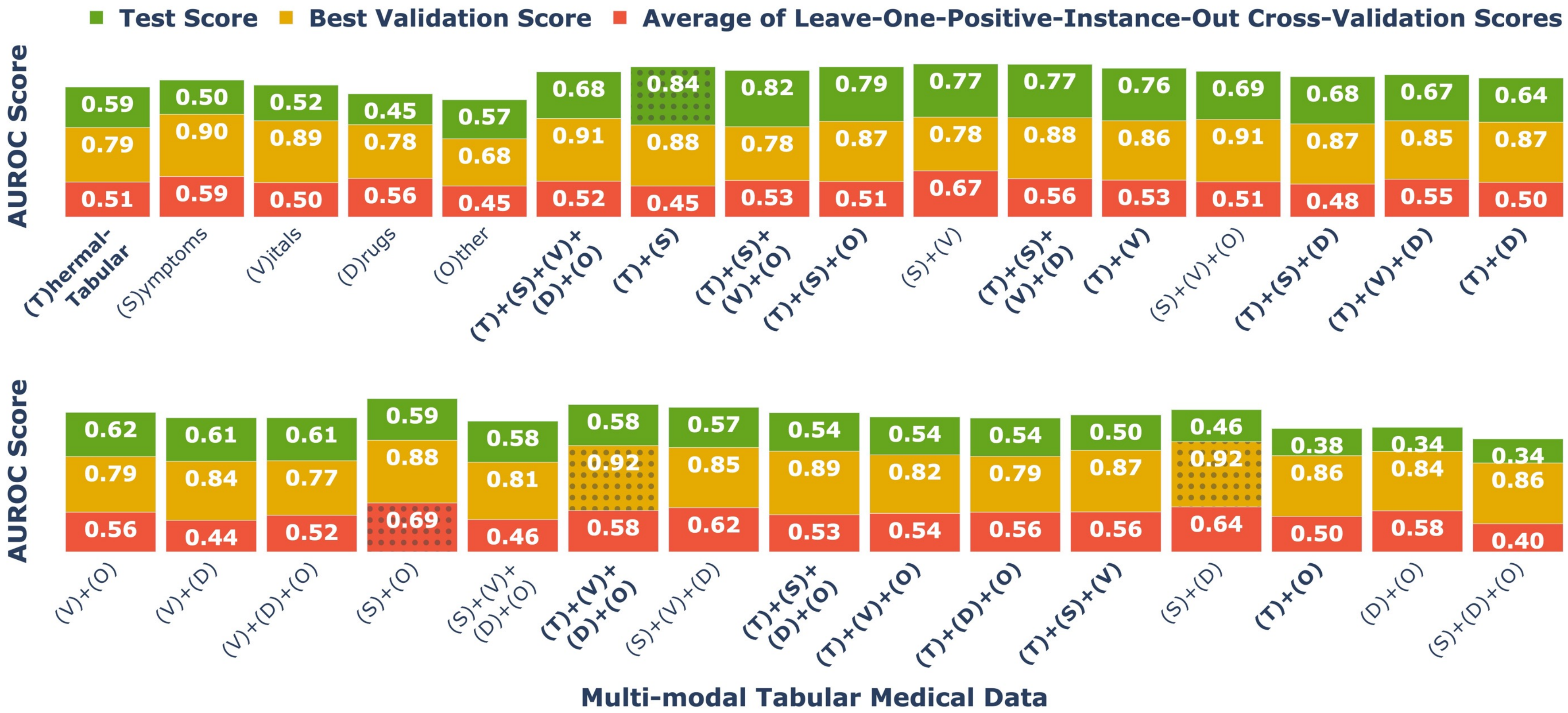
Multi-modal Tabular Medical Data

Multi-Modal COVID-19 Detection AUROC Results using MLP with Tabular Medical Data

Best Test Score: 0.84 **Overall Best Validation Score: 0.92**

Best Average of Leave-One-Positive-Instance-Out Cross-Validation Scores: 0.69

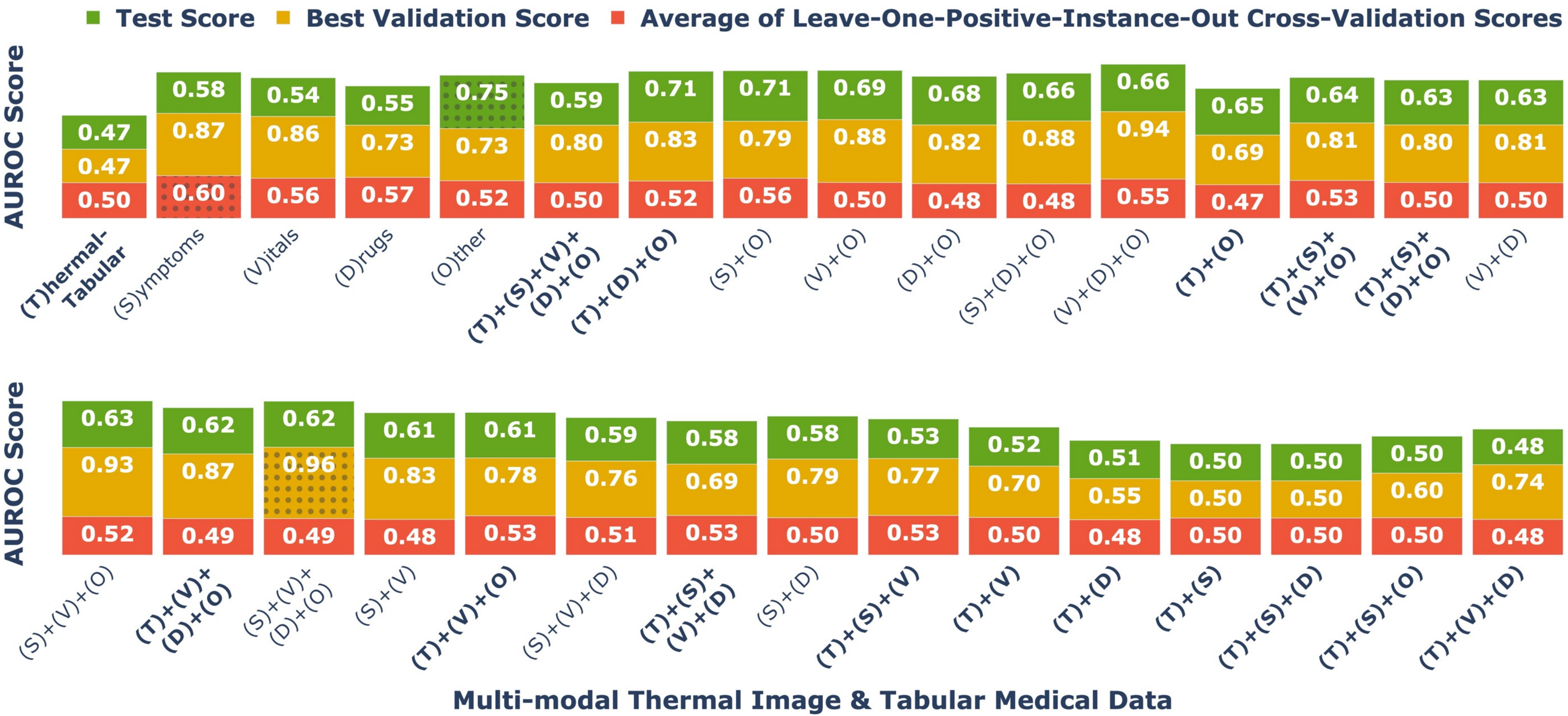


Multi-Modal COVID-19 Detection using CNN+MLP with Thermal Image & Tabular Medical Data

Best Test Score: 0.75

Overall Best Validation Score: 0.96

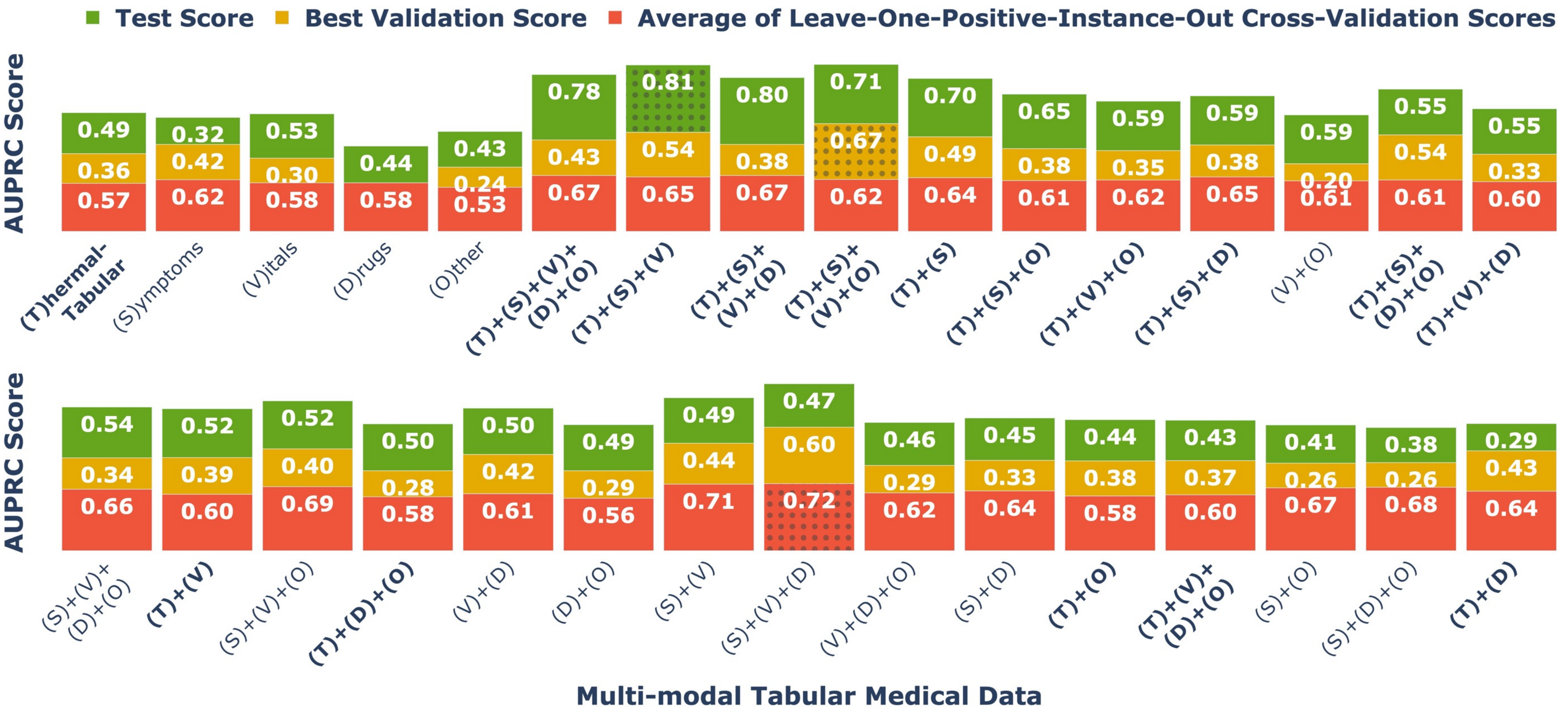
Best Average of Leave-One-Positive-Instance-Out Cross-Validation Scores: 0.60



Multi-Modal COVID-19 Detection AUPRC Results using XGBoost with Tabular Medical Data

Best Test Score: 0.81 **Overall Best Validation Score: 0.67**

Best Average of Leave-One-Positive-Instance-Out Cross-Validation Scores: 0.72



Key Insights

Machine Learning Techniques

- Utilized XGBoost, random forests, MLP, and CNN+MLP models
- Decision driven by research on limited data performance and advantages of gradient boosting algorithms for tabular data

Experimental Results

- Multi-modality showed better performance than single modalities with thermal image information
- XGBoost and random forests models outperformed MLP and CNN+MLP models for COVID-19 detection
- Leave-one-positive-instance-out cross-validation did well with small dataset
- AUPRC scores indicated robust performance despite imbalanced data

Benefits

- Safe, low-cost, non-invasive, and fast detection technique
- Remote deployment with minimal human contact for monitoring and diagnosis
- Potential effectiveness in pandemic situations
- Increased robustness and modularity in the system
- COVID-19 detection can be achieved even with missing data
- Flexibility in using various devices and data sources

Future Possibilities

- Utilizing Internet of Medical Things (IoMT) and wearable sensors for real-time COVID-19 detection
- Integration of vital signs, symptoms, clinical records, and thermal imaging
- Remote machine learning training and detection using low-cost edge devices
- Secure aggregation of devices and training models using federated learning or swarm learning approaches

Image Source

[1] https://www.who.int/health-topics/coronavirus#tab=tab_1

[2] https://demigos.com/blog-post/healthcare-data-visualization/

[3] https://www.securitysales.com/surveillance/thermal-imaging-trends-looking-up/

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[8] https://riptutorial.com/machine-learning/example/14446/area-under-the-curve-of-the-receiver-operating-characteristic--auroc-

[9] https://stackoverflow.com/questions/53772249/how-to-evaluate-accuracy-on-highly-unbalanced-data-using-naive-bayes-model

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Thank You!