CNN-based Deep Learning-Enabled Tool for Winter Roadway Condition Monitoring

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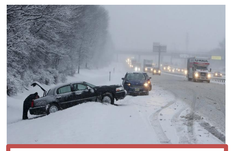
Introduction & Background

Introduction



21% of All Vehicle Crashes are Weather-related in U.S.

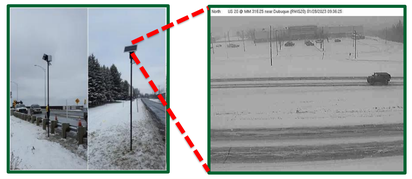
Winter Traffic Mobility Capacity 44%↓ Speed 17%↓

Winter Maintenance Annual Cost In U.S. Direct $2.3B Indirect $5B

❖ Winter challenges road safety and mobility with snow and ice, necessitating effective maintenance strategies. While Road Weather Information Systems (RWIS) equipped with cameras have improved the monitoring of road conditions, the manual analysis of Road Surface Conditions (RSC) captured by these cameras is still time-inefficient and labour-intensive.

RWIS Database:

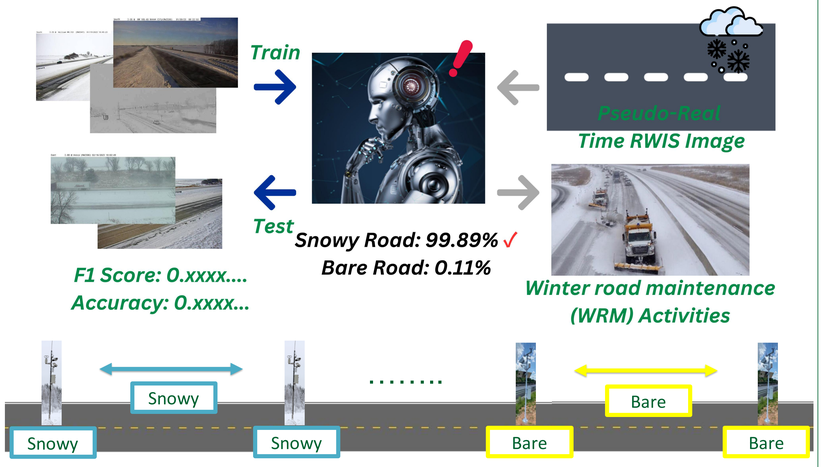
- ***Camera Data***
- Traffic Data
- Atmospheric Data
- Surface Data



Background

❖ Advances in artificial intelligence and computer vision allow for the automated monitoring of RSC through RWIS image analysis. This enables real-time monitoring and reduces labor costs, which are vital for improving road safety and efficiency during winter.

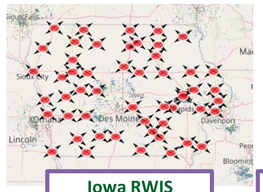
Objectives



❖ The objective is to improve winter road monitoring with Convolutional Neural Networks (CNN) to enable near real-time RSC monitoring by interpolating between RWIS points.

Methodology

Study Area & Data Collection



Iowa RWIS Location

Stationary RWIS Dec 2022 – Feb 2023

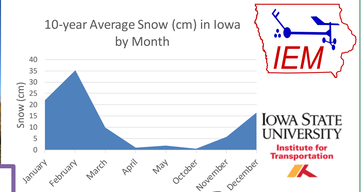
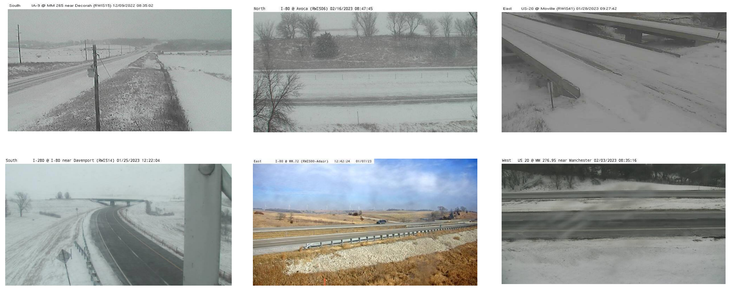
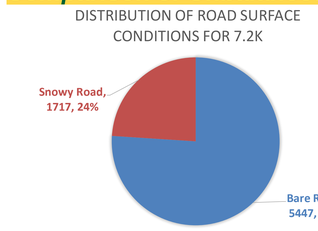
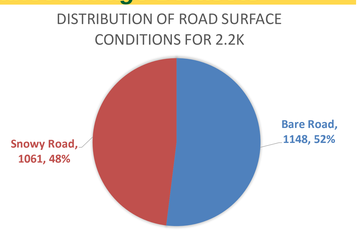


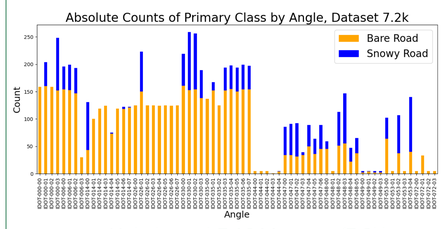
Image Labelling



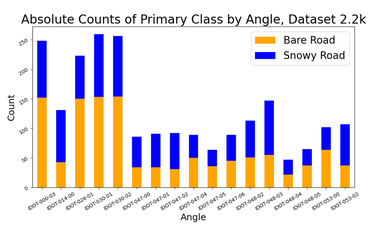
Comparison of Unbalanced and Balanced Image Datasets





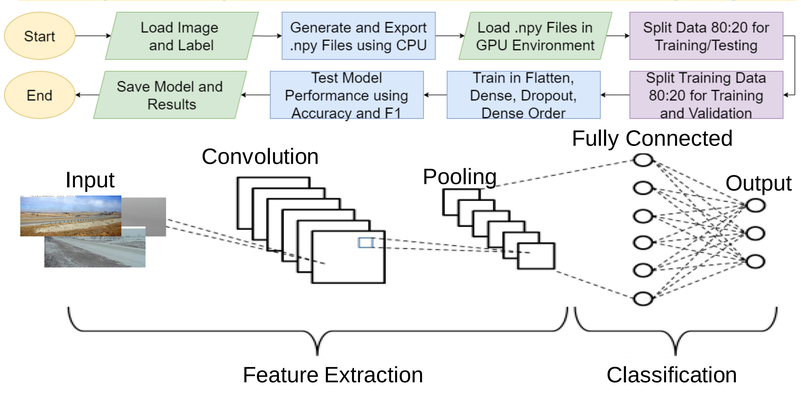


Unbalanced 7,164 Images (7.2k)
67 Individual Angles



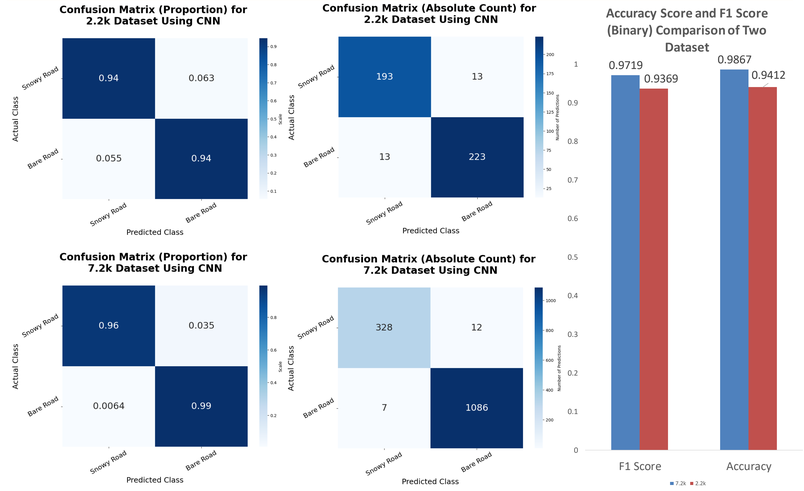
Balanced 2,200 Images (2.2k)
17 Individual Angles

Training & Testing with Convolutional Neural Networks (CNN)

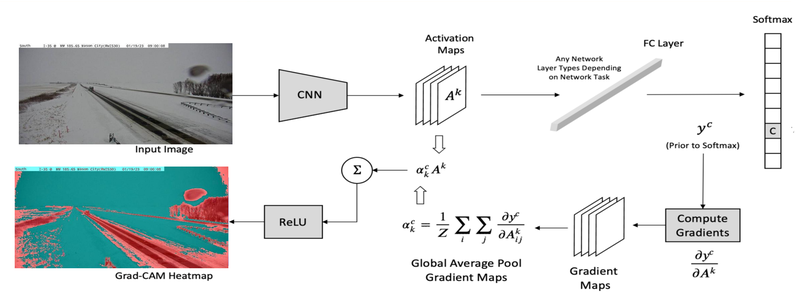


Results

Performance Evaluation and Results Analysis



Grad-CAM: Visual Explanations via Gradient-based Localization



❖ Grad-CAM enhances CNN interpretability by highlighting image regions most influential in classification, such as snow or bare pavement, offering insights into model decisions and improvement areas.

Conclusions

❖ A CNN-based deep learning model was developed to automate RSC recognition from stationary RWIS images, demonstrating high accuracy in training and validation. Its success not only proves its precision in identifying RSC but also showcases its potential in advancing towards a pseudo-real-time road condition monitoring system, offering significant cost and labor reductions in road safety operations.

Acknowledgement

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