Regular and Thermal Cameras

Data Collection Under Varying Lighting and Temperature Conditions in Multimodal Environments

Presenter: Ting Fu
Supervisor: Luis Miranda-Moreno, Nicolas Saunier

McGill
École Polytechnique Montréal

Outline

- Introduction
- Literature Review
- Methodology
- Data Description
- Results
  - Detection
  - Classification
  - Speed Measurement
- Conclusions

Introduction

- **Traffic data is essential in road safety analysis.** Detection-based technologies (loops and radars) do not provide spatial coverage or do not capture non-motorized road users [1]
  - We require methods for collecting data from all road users
- Besides, in road safety analysis
  - **Crash data** is not always available in sufficiently large quantity
  - It suffers from known problems: low-mean small sample, underreporting, mislocation and misclassification
  - It requires long periods of observation – Because of a lack of after-treatment data; it is hard to validate recent treatments[5]
  - Therefore, proactive methods do not require to wait for crashes to happen, are proposed – **surrogate measures of safety,** such as traffic conflict techniques (TCT)

Introduction

- These facts and issues in traffic data collection and road safety analysis have spurred the development of non intrusive data collection methods, such as **video-based devices**
  - They provide trajectories of **pedestrians, bicycles, and vehicles**, which are essential to understand behavior and safety in a multimodal context
  - Vision-based monitoring provide rich **positional and classification data** [2] – key elements in conflict analysis

- There are **several limitations** of regular cameras:
  - Extracting data from video footage requires computer vision techniques [3]
  - Accuracy is dependent on **lighting, shadow, and weather conditions** [4]
  - So, existing computer vision approaches may not work under all conditions [3]

Introduction

- New technologies, including thermal cameras, have become available
  - Consider potential for **an around-the-clock** video-based traffic sensor [2]
- The performance of tracking and classification algorithms has not been tested and evaluated when using thermal video sensors:
  - Performance across different lighting and visibility conditions is desired
- The purpose of this study is:
  - To integrate existing tracking and classification algorithms for automated data collection with thermal video sensors
  - To evaluate their performance of thermal video sensors under different lighting and pavement temperature conditions with respect to road user detection, classification, and vehicle speed measurements

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Literature Review

Existing Shortcomings

- Detection rate alone is **too limited** to represent performance
  - The whole confusion matrix should be presented
  - Separate calibration and validation data sets should be required
- Most studies **cannot be reproduced** since the software or datasets are not available
- Limited work on detecting and classifying multiple road user types from thermal video in **mixed-traffic environments**
- No attempt to measure the effect of **pavement temperature** on the quality of thermal video

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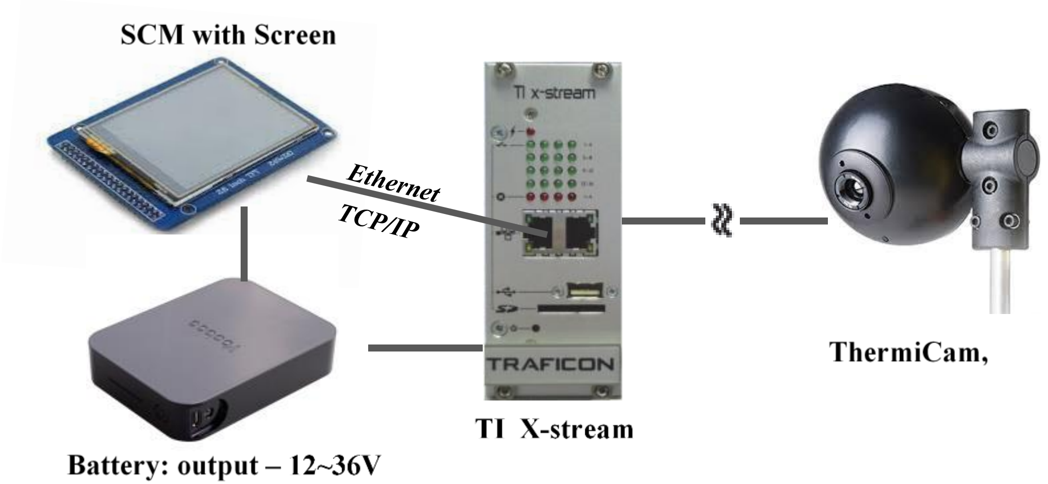
Methodology

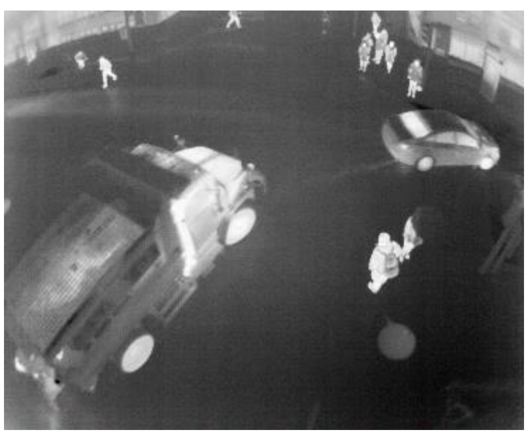
Thermal Camera System



a) System components. *In the field, the battery, SCM and the TI X-stream are enclosed in a small waterproof case*

b) System enclosure

c) Installation



d) Sample of thermal video

Methodology

Tracking and Classification Output

Methodology

Detection Performance

- Videos were processed using Traffic Intelligence
  - An open-source computer-vision software project [5].
  - More detail provided in Shi and Tomasi [6] and Saunier [5]
- Miss rate was used to quantify detection performance
  - The proportion of road users whose movement is not detected or tracked
  - Any individual road user or group of road users with consistent motion not tracked by the algorithm is considered as one miss

Methodology

Classification Performance

- Classification performed using the method in Zangenehpour et al. [7]
  - Road users are classified based on **appearance, speed, and location**
- The classifier was trained on a dataset of 1500 regular images and 1500 thermal images of each road user type
- **Precision, recall, and accuracy** used to measure performance

$$Precision_k = \frac{TP_k}{TP_k + FP_k} = \frac{C_{kk}}{\sum_i C_{ik}}$$

$$Recall_k = \frac{TP_k}{TP_k + FN_k} = \frac{C_{kk}}{\sum_j C_{kj}}$$

$$Accuracy = \frac{TP}{TP + TN} = \frac{\sum_k TP_k}{\sum_k TP_k + TN_k} = \frac{\sum C_{kk}}{\sum_i \sum_j C_{ij}}$$

Methodology

Vehicle Speed Validation

- Once road users have been detected and classified, parameters including vehicle speed can be extracted
- Vehicle speed accuracy was quantified using measures suggested by Anderson-Trocmé et al. [8]
  - **Accuracy** is the systematic error or bias
  - **Precision** is the residual error

$$Relative\ Precision\ Error = \frac{1}{100}\sum \frac{|(V_{extracted} - y\ intercept) - V_{observed}|}{V_{observed}}$$

$$Relative\ Accuracy\ Error = \frac{1}{100}\sum \frac{|y\ intercept|}{V_{observed}}$$

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Data Description

Lighting Test Cases

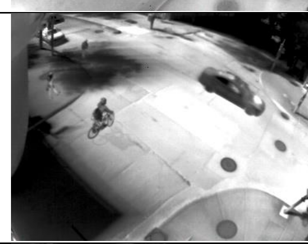
SAMPLE CAMERA VIEWS UNDER DIFFERENT LIGHTING CONDITIONS					
Daytime Conditions	**Thermal Camera**	**Regular Camera**	**Nighttime Conditions**	**Thermal Camera**	**Regular Camera**
Overcast			High visibility		
Sun, no shadows			Medium visibility		
Sun, strong shadows			Low visibility		

1

Data Description

Temperature Test Cases

SAMPLE CAMERA VIEWS UNDER DIFFERENT TEMPERATURE

Pavement Temp.	Camera View	Pavement Temp.	Camera View
0 °C- 5°C		35 °C-40°C	
20 °C-25°C		40 °C-45°C	
25 °C-30°C		45 °C-50°C	
30 °C-35°C			

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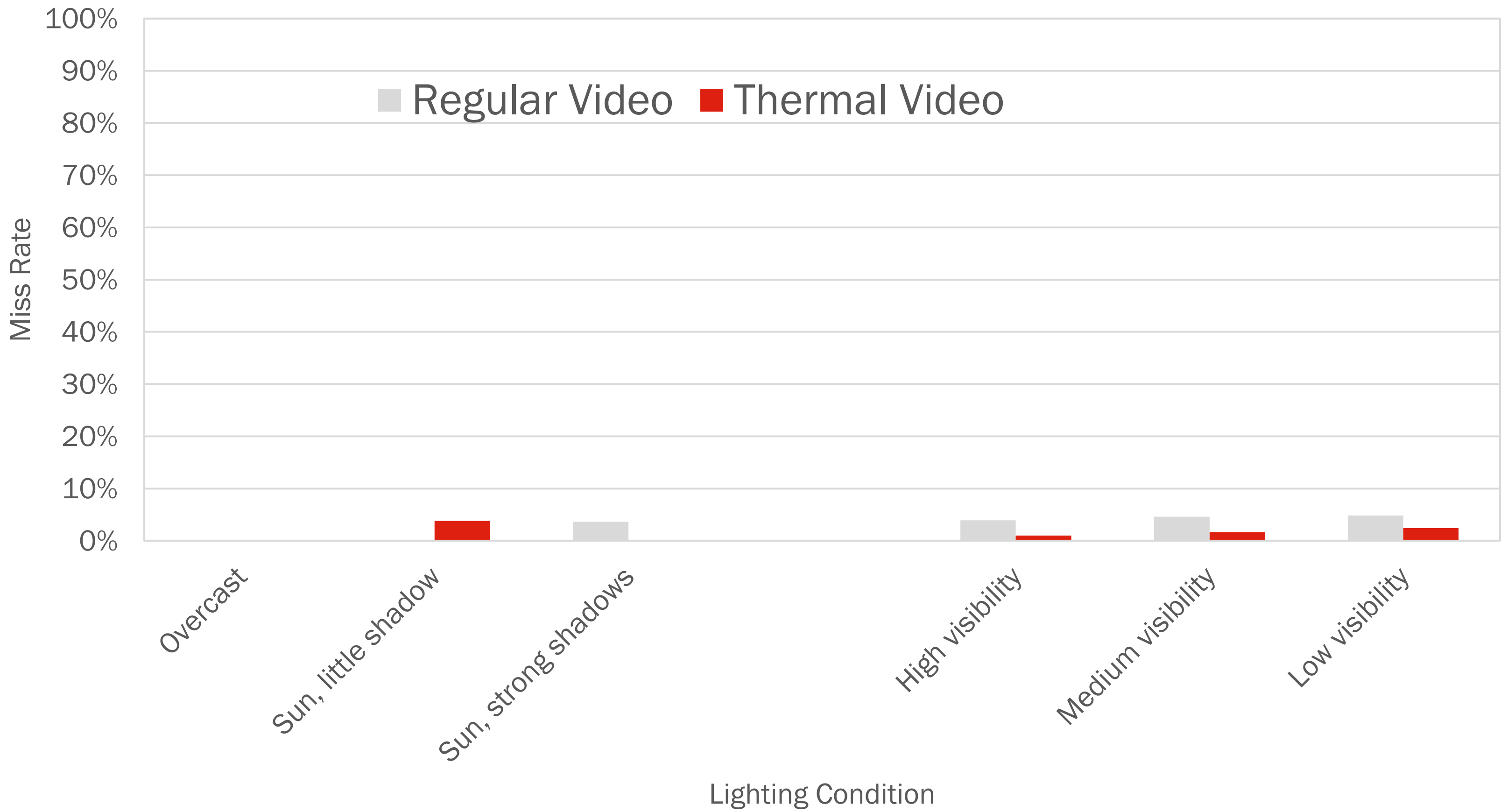
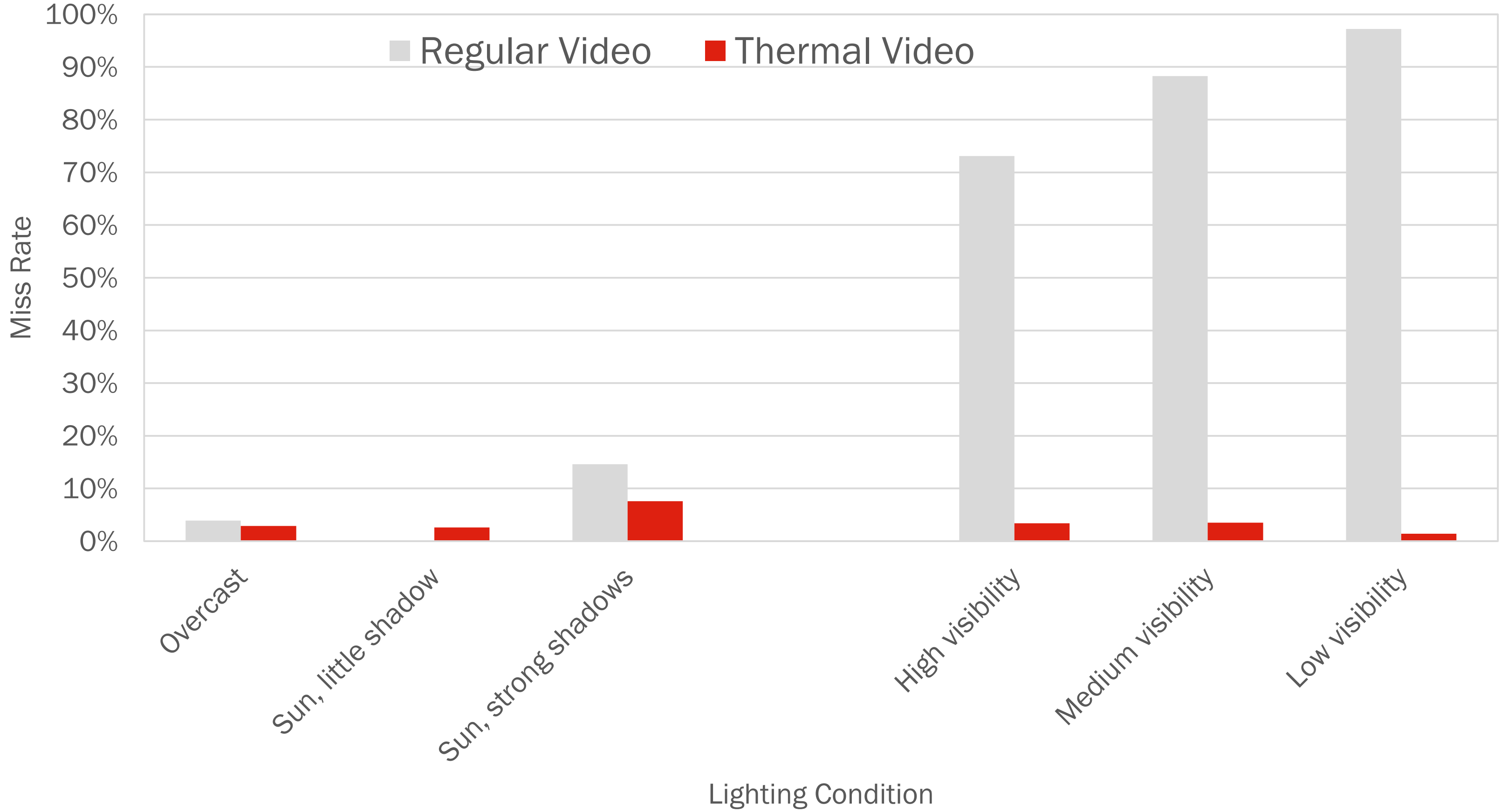
Results

Detection Performance – Vehicles



Results

Detection Performance – Pedestrians



Results

Classification Performance – Vehicles

		Thermal Video		Regular Video	
Lighting Condition		**Precision**	**Recall**	**Precision**	**Recall**
	Overcast	53.3%	97.0%	78.9%	99.3%
Daytime	Sun, little shadow	46.3%	100.0%	67.9%	100.0%
	Sun, strong shadows	44.2%	100.0%	55.0%	100.0%
	High visibility	66.7%	91.2%	74.5%	97.6%
Nighttime	Medium visibility	99.0%	96.2%	97.2%	99.5%
	Low visibility	56.3%	96.4%	91.4%	100.0%

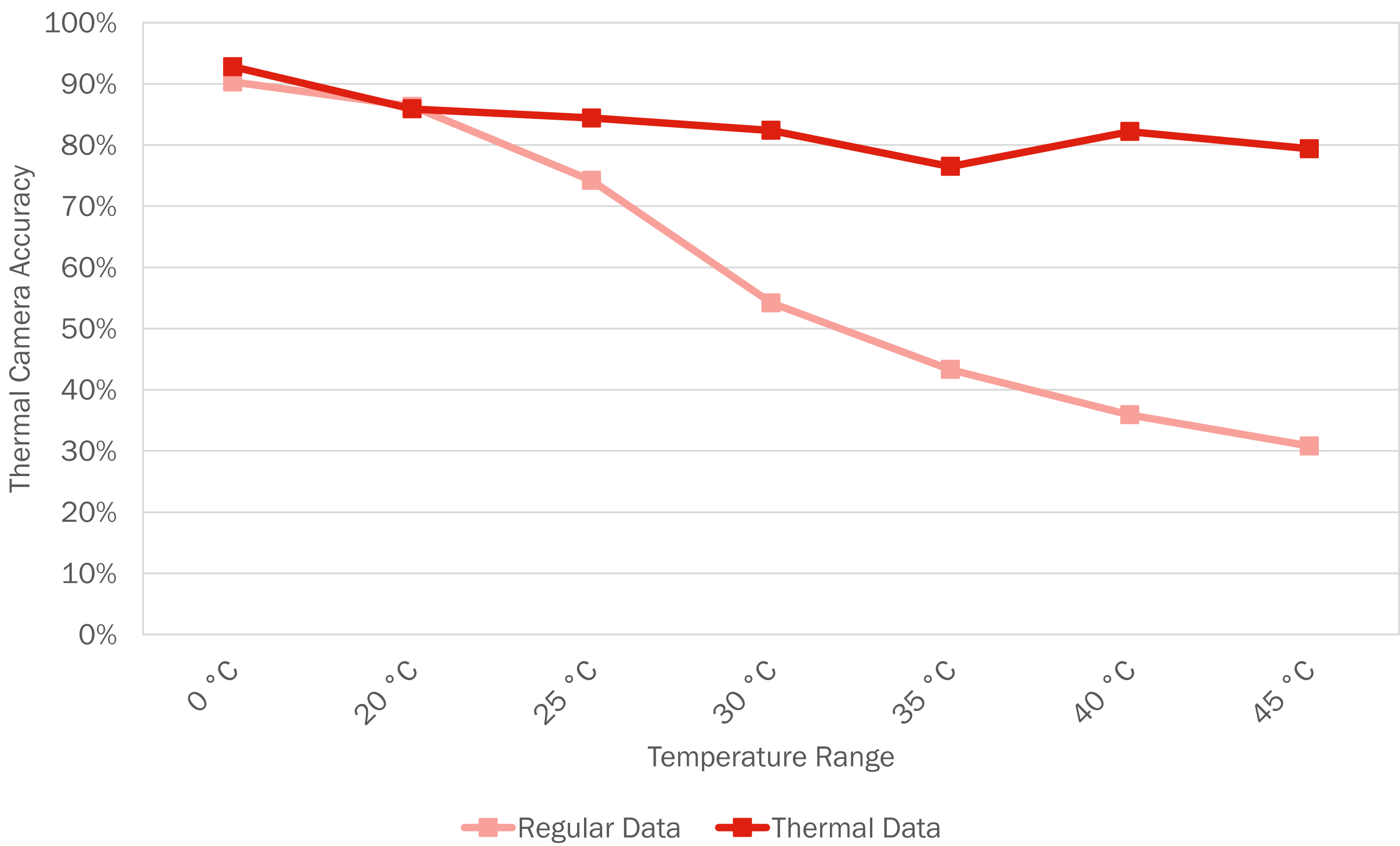
Results

Classification Performance – Pedestrians

		Thermal Video		Regular Video	
Lighting Condition		**Precision**	**Recall**	**Precision**	**Recall**
	Overcast	98.3%	68.5%	99.1%	68.3%
Daytime	Sun, little shadow	82.1%	56.1%	93.8%	66.2%
	Sun, strong shadows	100.0%	46.8%	86.6%	59.2%
	High visibility	97.8%	68.9%	90.0%	25.7%
Nighttime	Medium visibility	94.5%	94.5%	100.0%	14.3%
	Low visibility	99.5%	89.5%	0.0%	0.0%

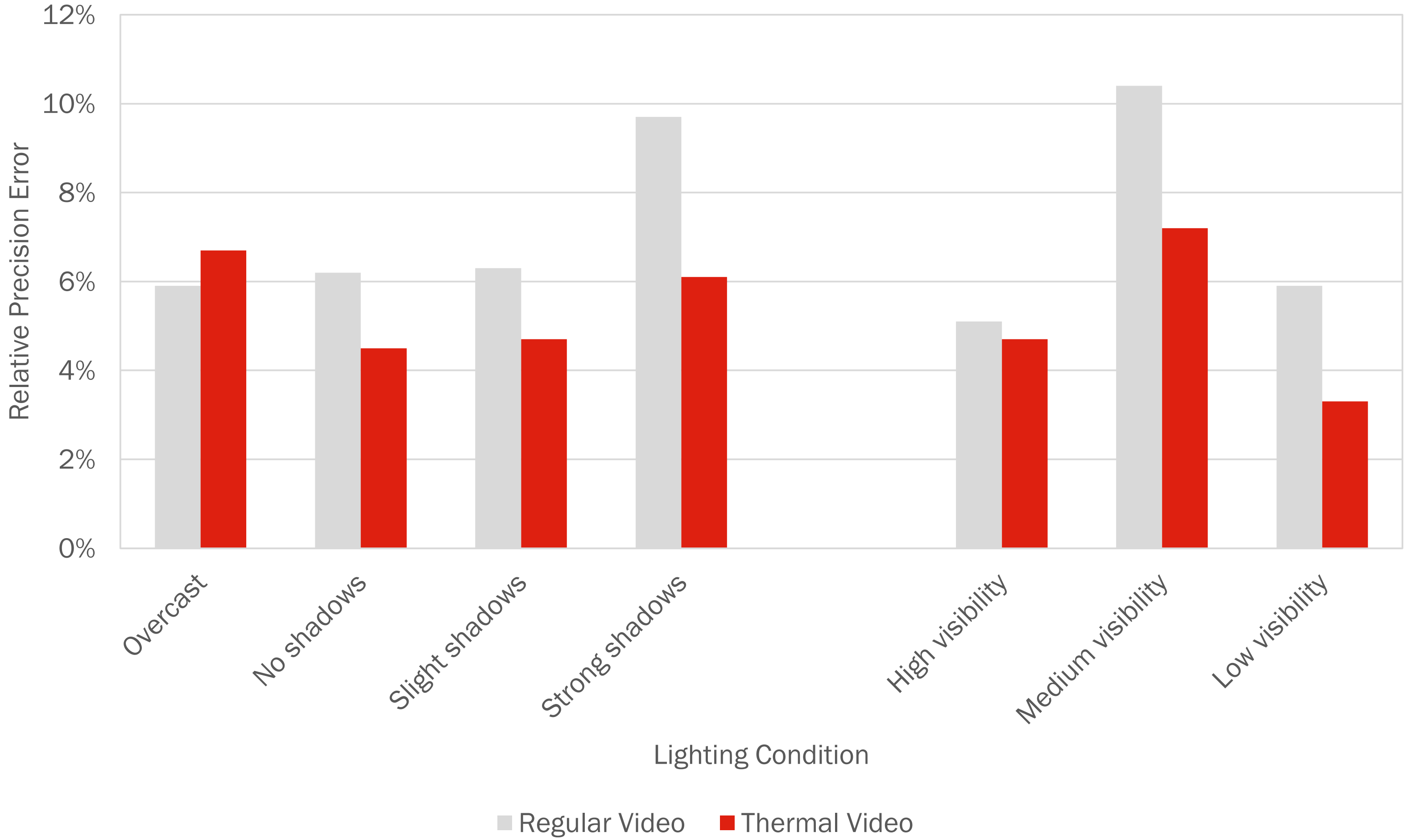
Results

Classification Performance - Temperature



Results

Vehicle Speed Validation



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Conclusions

- Detection and classification of all road users during daytime conditions is similar for the two camera systems
  - In the regular video, miss rate is **much higher** for pedestrians and cyclists in all nighttime test cases
  - Thermal camera miss rate **remained low** even at night
- Training of the classifier on **thermal video data** improved performance for the thermal camera
- Speed measurement by the thermal camera was **consistently more precise** than measurements by the regular video
  - Thermal camera performance was generally insensitive to lighting and temperature conditions

Conclusions

Future Work

- Evaluation of thermal video in **adverse weather conditions**, such as heavy precipitation and fog, is a key focus of future work
- Future work should quantify detection performance using **precision and recall** on individual user basis rather than miss rate at the group-level
- As video techniques are promising, we are currently conducting field data collection using both regular cameras and thermal cameras for validating crosswalk safety in both daytime and nighttime in downtown Montreal. Some interesting results have been found. Hopefully, I can provide more details for the next CARSP Conference.

References

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Acknowledgements

Coauthors

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- Luis Miranda-Moreno, Associate Professor, McGill University
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Thank you!

Questions or comments?

ting.fu@mail.mcgill.ca