UAV-based Thermal Imaging for Detecting Near-Surface Voids on Roadway Pavements using Computer Vision and Deep Learning Algorithms

Kaiwen Chen, Yasser EI Masri, Hala K. Alfalih, Steven Kangisser, Tarek Rakha and Javier Irizzry

Georgia Institute of Technology

Abstract

Near-surface voids can develop into *potholes* and *spalling* causing potential driving hazards.

A UAS with dual camera sensors can efficiently collect ***infrared (IR)*** and ***visual (RGB)*** images.

This research studied the application of ***Computer Vision*** and ***Deep Learning*** to analyze UAV-collected multi-spectrum images to detect areas with voids beneath pavement surfaces.

Introduction

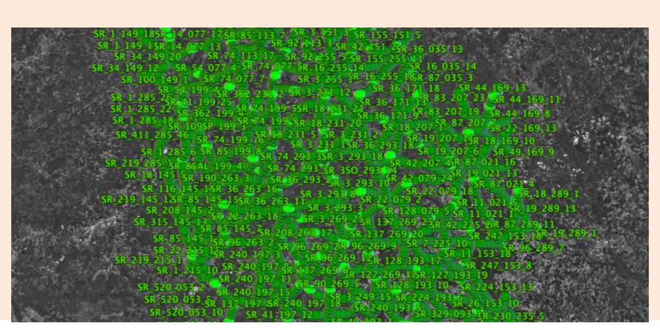
Pavement Near-Surface Voids

- **Definition**: subsurface voids in asphalt that are not visible to the naked eye
- **Hazards**: at a risk of becoming dangerous potholes on the road
- **Detection**: using IR to detect temperature differences caused by variable thermal conductivity
- **Repairs**: early identification for preemptively repair saving lives

UAV for Pavement Inspection

- UAV systems: unmanned aerial vehicle safer, lower risk capacity, time saving, less site disruption, decreased cost, more accurate and precise data.
- UAV workflow:

1) DOT roadmap
2) Fly UAV for images
3) Repair & report

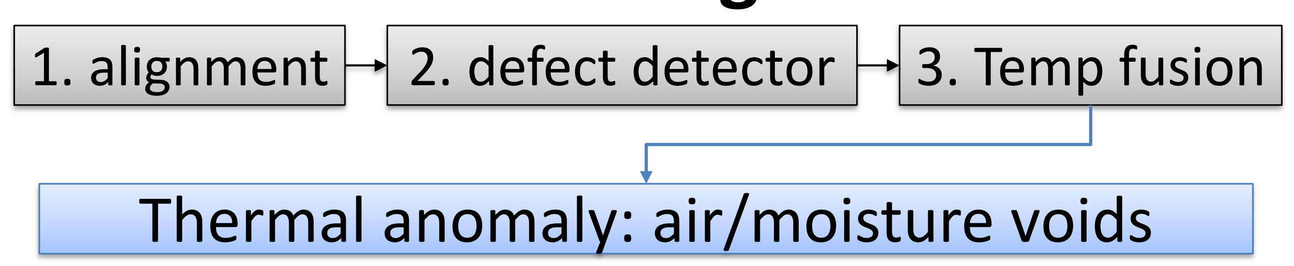


Material & Methods

Data Gathering

Location: NCAT Facility in Opelika AL.
Drone model: DJI Matrice 200
Camera model: Zenmuse XT2
IR Resolution: 640 × 512

Detection Algorithm

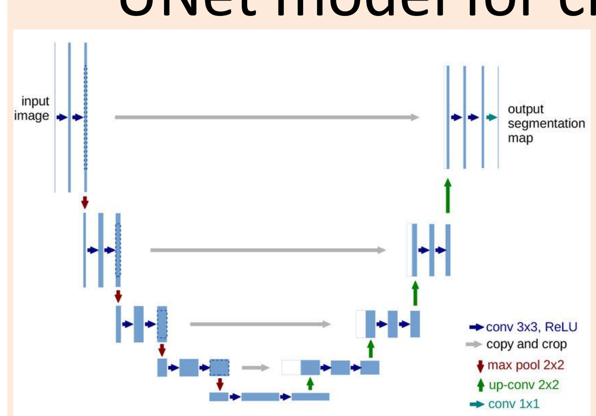


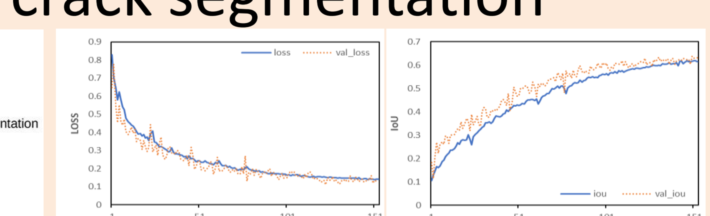
1. Alignment of IR and RGB Pairs

- **Un-distortion by SfM:**
  1) Camera matrix = *[[fx, 0, cx], [0, fy, cy], [0, 0, 1]]*
  2) Distortion coefficients = *[k1, k2, p1, p2, k3]*
- **ORB-ASIFT matching:**
  1) Open ASIFT image feature keypoint detector
  2) Affine transformation by detected matches

2. RGB Crack Detector (UNet)

- UNet model for crack segmentation





	Precision	Recall	F1-score
Train	97.47	97.95	97.70
Validation	97.28	97.23	97.26
Test	96.97	97.15	97.08

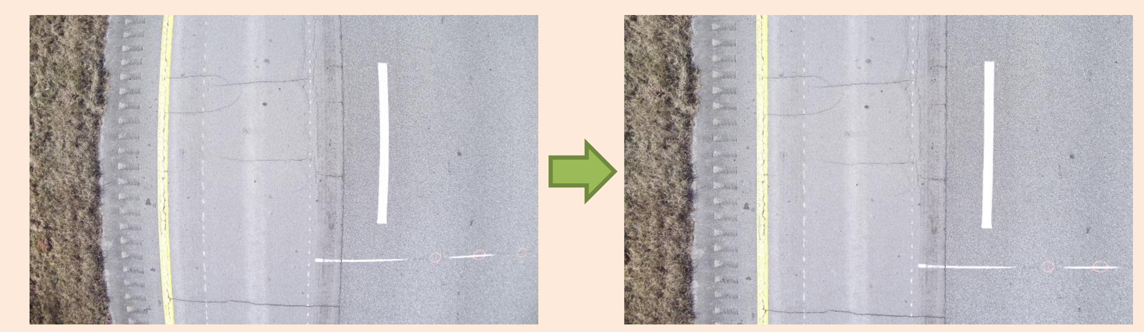
3. Fuse with Thermal Data

1) Binary crack segmentation
2) Dilate crack regions
3) Multiply with IR temp data
4) Normalize temperature colormap

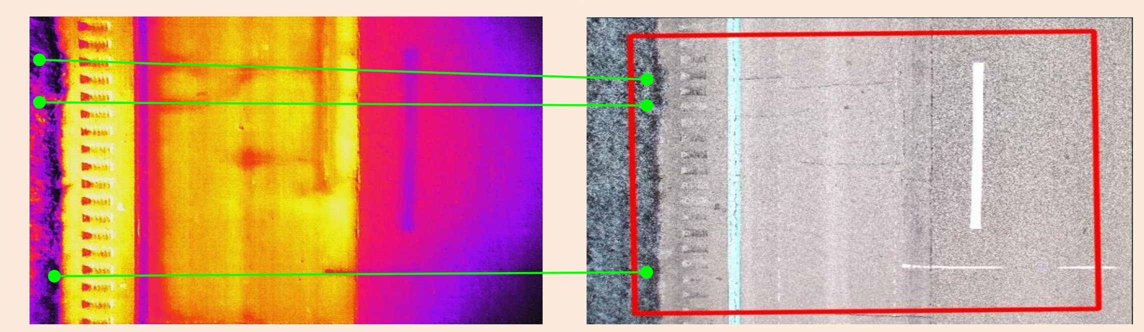
Results

1. Alignment of IR and RGB Pairs

- Duo camera un-distortion

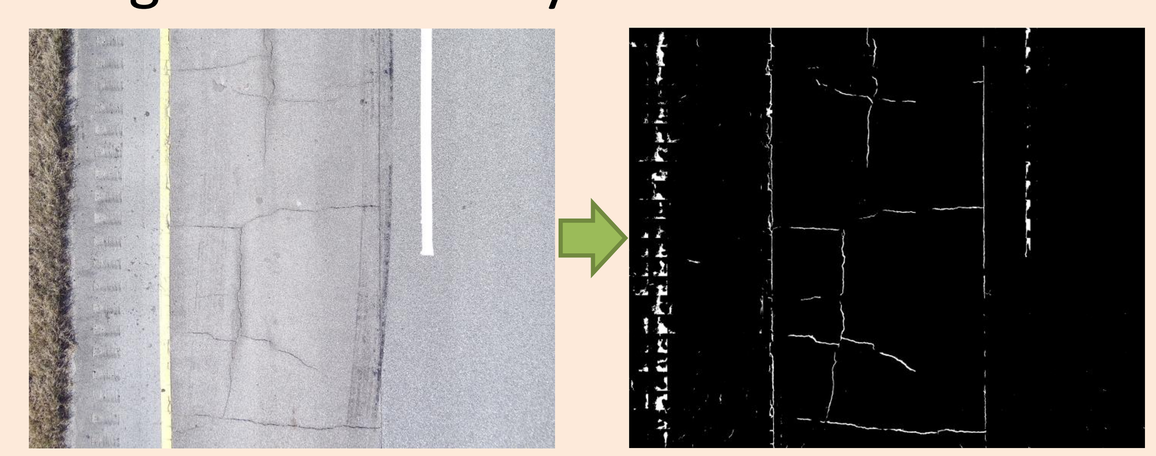


- ORB-ASIFT matching



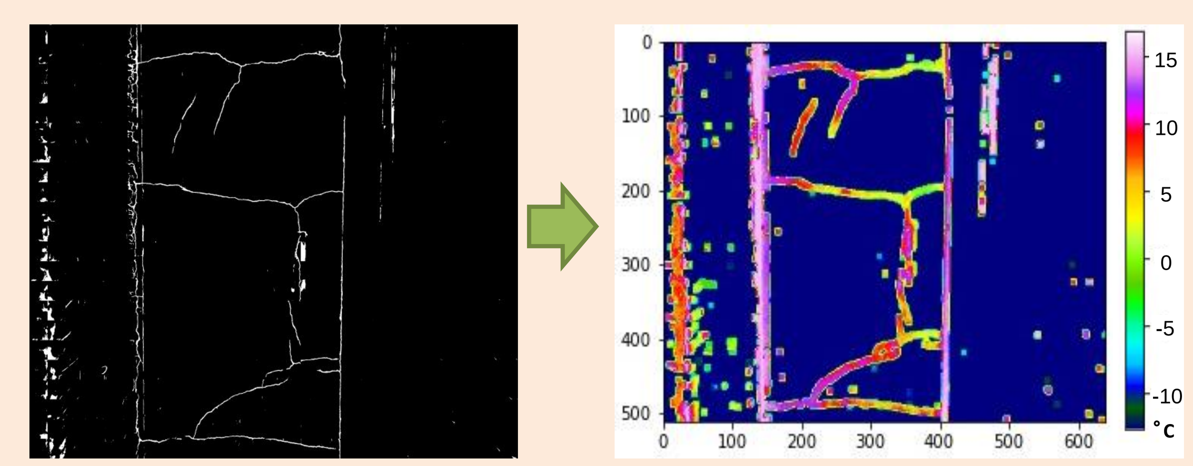
2. RGB Crack Detector (UNet)

- Segment cracks by trained Unet model



3. Fuse with Thermal Data

- Crack with Thermal Information



- Thermal anomalies –> Near-surface voids

1) Potential voids beneath surface
2) Voids containing air, moisture

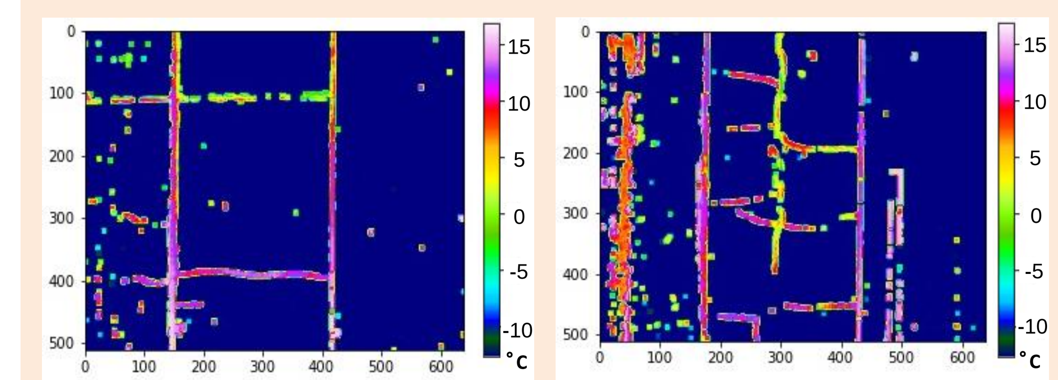
Conclusions

Summary & Innovation

- Apply UAV-collected IR/RGB data
- Analyze detected visible cracks to identify thermal anomalies indicating near-surface voids
- Automate crack detection and analysis by computer vision and deep learning methods
- Reproducible and reusable computational tools for UAV-based pavement inspections

Limitation & Future research

- Assess severity level of identified near-surface voids with GPR
- Explore appropriate conditions for IR image collection by UAVs



References

J.M. Morel and G.Yu, ASIFT: A New Framework for Fully Affine Invariant Image Comparison, SIAM Journal on Imaging Sciences, vol. 2, issue 2, 2009.

J. Yang, W. Wang, G. Lin, Q. Li, Y. Sun, Y. Sun, Infrared Thermal Imaging-Based Crack Detection Using Deep Learning, IEEE Access. 7 (2019) 182060–182077.

S. Pozzer, E. Rezazadeh Azar, F. Dalla Rosa, Z.M. Chamberlain Pravia, Semantic Segmentation of Defects in Infrared Thermographic Images of Highly Damaged Concrete Structures, J. Perform. Constr. Facil. 35 (2021) 04020131.