HAOLIN WANG

Ph.D. Student, Civil Engineering · Smart City Infrastructure Lab · Georgia Institute of Technology
Atlanta, GA · hwang972@gatech.edu · +1 (770) 680-8633
haolinwang.com Google Scholar GitHub 0009-0008-7186-7409

RESEARCH SUMMARY

My research makes pavement condition data trustworthy enough to drive **life-cycle maintenance decisions**. Over four years at Georgia Tech's Smart City Infrastructure Lab I have (1) established how to **assess and standardize cracking-data quality** across state DOTs (NCHRP 01-57B; Transportation Research Record), (2) developed methods that **align repeated and multi-sensor surveys** so that true deterioration can be measured over time, (3) designed **evaluation metrics and open benchmarks** for crack-detection models, and (4) connected condition data to **treatment decisions and automated maintenance**. My dissertation integrates this work into a **digital twin of pavement cracking**: an end-to-end pipeline that turns millimeter-resolution 3D surveys into persistent crack objects, keeps them synchronized across survey cycles and sensing modalities, propagates measurement uncertainty from data collection to the final condition rating, and uses the resulting state to **track deterioration across the pavement life cycle**, prioritize treatment timing and location, and plan robotic crack sealing. I pair this with four years of teaching data analytics and AI for civil engineering, currently as Head TA, recognized by Georgia Tech CEE's Bill Schutz Graduate Teaching Assistant Award.

EDUCATION

Georgia Institute of Technology, Atlanta, GA

Ph.D. in Civil Engineering (Construction and Infrastructure Systems Engineering) Jan 2024 – Expected Fall 2027

- Dissertation: *Toward a Digital Twin of Pavement Cracking: Uncertainty-Aware Creation, Structured Diagnosis, and Treatment Prescription* (proposal in preparation, Fall 2026)
- Advisor: Dr. Yi-chang (James) Tsai · GPA 4.00

M.S. in Computer Science & Engineering Aug 2022 – Dec 2024

Tongji University, Shanghai, China

B.Eng. in Civil Engineering · GPA 3.89 · Excellent Graduate (2021) Sept 2017 – June 2021

RESEARCH EXPERIENCE

Graduate Research Assistant, Smart City Infrastructure Lab, Georgia Tech (PI: Dr. James Tsai) Jan 2023 – Present

Projects funded by NCHRP and GDOT. Work is organized below by the three stages of the pavement-cracking digital-twin framework that structures my dissertation (creation, synchronization, and application), plus the evaluation and standardization work that makes the twin trustworthy. Together, these stages connect raw survey data to life-cycle performance monitoring and maintenance decisions.

1. Digital Twin Creation: cracking data quality, uncertainty, and crack-object extraction

- Proposed a two-level methodology for **assessing cracking-data quality** against ground references: an end-to-end coarse-to-fine crack-map comparison plus a decomposed diagnosis separating sensor limitations from detection-algorithm failures; validated across pavement types, sensing systems, and algorithms in Florida, Mississippi, and Texas, giving agencies a known-quality basis for the condition histories used in performance modeling and life-cycle decisions (Transportation Research Record, accepted).
- Leading an **uncertainty-quantification** study that traces how error enters at each step **of the crack-measurement pipeline** (data collection, crack segmentation, vectorization, and aggregated metrics) and how much of it survives to the final condition rating, using repeat-run 3D laser surveys of US-80 as the empirical benchmark, so that year-to-year condition changes can be distinguished from measurement noise in deterioration modeling (manuscript in preparation).
- Maintain and extend the lab's **Crack Vector Model (CVM)** library, which **converts crack masks and range images into topological node–link crack graphs** with per-link width, length, and orientation.
- Co-authored a review of **deep-learning crack detection** (learning paradigms, generalizability, datasets) (arXiv 2025).
- Designing **structure-aware thin-crack detection** that reduces crack fragmentation on 3D range images by **predicting crack centerline and width alongside the mask** and then **decoding continuity across gaps** where depth evidence is weak; the study tests image rendering, topology-aware losses, and orientation-guided decoding as sources of improvement (early stage).

2. Digital-Physical Synchronization: multi-temporal and cross-modal data alignment and calibration

- Co-developed a **feature-based registration method** aligning repeated 3D pavement surveys so **true deterioration can be separated from image-offset artifacts**, enabling crack-level deterioration tracking across survey years (Computer-Aided Civil and Infrastructure Engineering, 2025).
- Defining and co-developing an **unsupervised deep-learning method** for **deformable multi-temporal crack-map registration** in support of crack-propagation monitoring (manuscript in preparation).
- Developing and validating a pipeline for using **low-cost RGB (dashcam) imagery as a surrogate for high-resolution 3D laser surveys**, enabling **more frequent, cost-effective monitoring** between survey cycles and a finer temporal resolution for life-cycle condition histories: calibrating how crack information degrades from laser to RGB on co-registered pairs, testing whether the surrogate preserves the crack measures agencies act on, and triggering high-resolution updates only where change is detected (manuscript in preparation).

3. Digital Twin Application: crack condition assessment, deterioration tracking, and treatment prescription

- Proposed a **link-level crack-density indicator** on the CVM graph that **replaces grid-based density** (ASTM E3303) with a buffer around each crack link; calibrated and cross-validated on 150 crack maps spanning four crack types and road classes for **alligator-crack classification**, providing a consistent severity measure for treatment selection (ASCE Journal of Computing in Civil Engineering, in revision).
- Formalized **robotic crack-sealing path planning** as a **sliding-window arc-routing problem** (a Rural Postman Problem variant) in which a sealing vehicle advances along the lane while a robotic arm must trace every crack within operating constraints under a full-coverage requirement, lowering the cost of preventive maintenance that extends pavement service life; **benchmarking solvers** (manuscript in preparation).

4. Auxiliary toolbox: supporting methods for the pipeline

- **Lane-marking detection for wheelpath-based distress measurement**: built **OrthoLaneMark**, a 1,391-image **presence-aware benchmark** on orthographic 3D-laser imagery with a Gated Region Accuracy metric and nine re-implemented detectors across four mechanisms; established that wheelpath-region accuracy is bounded by presence reasoning rather than sub-pixel localization (journal submission, 2026; TRB 2027 presentation).
- Designed the **CRAck Structural Difference Index (CRASDI)**, a modular, **crack-topology-aware index** that **compares crack maps** as graphs and decomposes their difference into geometry, length, width, and orientation; benchmarked against six conventional metrics on 1,405 prediction–reference pairs across nine public datasets with dataset-wise Spearman rank correlation, and diagnosed atypical rankings caused by annotation irregularities, thin crack traces, and repeated prediction failures (CACAIE, under review). Released the **open-source Python package** and reproducibility scripts (github.com/THiNK327/CRASDI).

5. Standardization and framework development

- Core member of **NCHRP Project 01-57B** (Validating Standard Definitions for Comparable Pavement Cracking Data): developed and validated **quality-assessment and crack-definition protocols**, contributed to the Final Report, Tech Brief, **proposed revisions to AASHTO R 85**, and crack-data aggregation standard; co-authored responses to the panel ballot and presented to the panel and at RPUG 2025 and 2026.
- Conducting a **systematic review of pavement digital twins** for life-cycle maintenance and rehabilitation decision-making, framing creation, synchronization, and application as a **bidirectional twin loop**; presented the initial framework at the ACM SIGSPATIAL Workshop on Spatial Digital Twins (2025).

Undergraduate Researcher, Tongji University 2019 – 2021

- Nondestructive **acoustic-emission crack monitoring** for high-speed-railway ballastless track slabs, linking acoustic signatures to finite-element-simulated crack propagation; **two CNIPA patents** granted (Advisor: Dr. Yu Zhou).
- **Life-cycle maturity model of intelligent construction** in urban rail transit via literature review, questionnaires, and hierarchical analysis; recognized as an excellent project (Advisor: Dr. Yujie Lu).

PUBLICATIONS

*† / * denote equal contribution. Citation metrics: Google Scholar.*

Peer-reviewed journal articles

Wang, H.†, Yang, Z.†, Geary, G. M., & Tsai, Y.-C. (2026). Standardizing cracking data quality assessment and quantification. *Transportation Research Record*. Accepted (Paper 25-01724); in press.

Yang, Z., Mohammadi, M., **Wang, H.**, & Tsai, Y.-C. (2025). A feature-based pavement image registration method for precise pavement deterioration monitoring. *Computer-Aided Civil and Infrastructure Engineering*, 40(10), 1276–1294. (IF 9.1, Q1)

Peer-reviewed conference and workshop papers

Tsai, Y.-C., **Wang, H.**, & Luo, S. (2026). Work in progress: A problem-solving systems approach to AI education: Lifecycle modules, inter-module reasoning, and values in practice. *2026 ASEE Annual Conference & Exposition*, Charlotte, NC. doi:10.18260/1-2--59094

Wang, H., & Tsai, Y.-C. (2025). Toward reliable pavement digital twins: Multi-scale spatiotemporal monitoring challenges and solutions. *Proceedings of the 1st ACM SIGSPATIAL International Workshop on Spatial Digital Twins*. doi:10.1145/3764924.3770893

Manuscripts under review or in revision

Wang, H.*, Yang, Z.*, Bao, J., Tsai, Y.-C., Geary, G. M., Cary, C., & Frith, D. J. A link-level crack density indicator based on the Crack Vector Model. *ASCE Journal of Computing in Civil Engineering*. In revision (CPENG-8858).

Wang, H.*, Ryu, S.*, Yang, Z., & Tsai, Y.-C. CRAck Structural Difference Index (CRASDI): A crack-topology-aware index for crack map comparison. *Computer-Aided Civil and Infrastructure Engineering*. Under review.

Wang, H., Luo, S., Yang, Z., & Tsai, Y.-C. Presence-aware benchmarking of lane-marking detection methods for pavement distress measurement. Submitted to an ASCE journal, September 2026; companion presentation accepted for the TRB 106th Annual Meeting.

Preprints

Zhang, X., **Wang, H.**, Hsieh, Y. A., Yang, Z., Yezzi, A., & Tsai, Y.-C. (2025). Deep learning for crack detection: A review of learning paradigms, generalizability, and datasets. arXiv:2508.10256

Zhang, X., **Wang, H.**, & Yang, Z. (2026). Towards successful implementation of automated raveling detection: Effects of training data size, illumination difference, and spatial shift. arXiv:2604.13322

Manuscripts in preparation (first author)

Wang, H., Yang, Z., & Tsai, Y.-C. Uncertainty quantification for pavement surface crack measurement. Target journal: Reliability Engineering & System Safety (draft complete; submission planned early 2027).

Wang, H., et al. Crack-sealing path planning as a sliding-window arc-routing problem: Problem definition and a benchmark of classical, exact, and learned solvers. Target journal: Computer-Aided Civil and Infrastructure Engineering (2027).

Wang, H., et al. Feasibility of low-cost RGB imagery as a surrogate for 3D laser pavement surveys: Calibration and cost-effective frequent monitoring. Target journal: Transportation Research Part C: Emerging Technologies (2027).

Wang, H., & Tsai, Y.-C. Digital twins for pavement maintenance and rehabilitation: A systematic review of creation, synchronization, and application. Target journal: Automation in Construction (2027).

Manuscripts in preparation (co-author)

Fung, J., **Wang, H.**, Lou, Z., Yang, Z., & Tsai, Y.-C. Unsupervised deep learning methodology for spatial-temporal pavement image registration. Target journal: Automation in Construction (2027).

Technical reports and standards contributions

Tsai, Y.-C., et al. (2026). Validating standard definitions for comparable pavement cracking data. *NCHRP Project 01-57B Final Report*, with appendices on crack-protocol design, data quality assessment, proposed revisions to AASHTO R 85, and crack-data aggregation. Transportation Research Board. (Contributing author)

OPEN-SOURCE SOFTWARE AND DATASETS

- **CRASDI** (**Wang**, Ryu, Yang, Tsai, 2026). Python package for crack-topology-aware crack-map comparison, with reproducibility scripts and per-pair results for nine public datasets. Software: doi:10.5281/zenodo.22117845; dataset: doi:10.5281/zenodo.22117905; code: github.com/THiNK327/CRASDI
- **OrthoLaneMark** (**Wang**, Luo, Yang, Tsai, 2026). Presence-aware benchmark for lane-marking detection on orthographic pavement imagery: 1,391 annotated images, evaluation framework, nine method implementations, and trained checkpoints. Dataset: doi:10.5281/zenodo.23003579; checkpoints: doi:10.5281/zenodo.23005229
- **TRACE** (Lou, Yang, **Wang**, Tsai, 2026). Temporal Registered Annual Crack-map Evolution, 20-sequence preview dataset. doi:10.5281/zenodo.22812774
- **Crack-sealing path-planning benchmark**: benchmarking solvers (heuristic, exact, reinforcement learning) with a reproducible pipeline on QA-checked road data (release planned with the manuscript).

CONFERENCE PRESENTATIONS

Presenter marked with ‡.

Wang, H., Luo, S., Yang, Z., & Tsai, Y.-C. (2027). Benchmarking lane marking detection methods for accurate pavement distress measurement. *Transportation Research Board 106th Annual Meeting*, Washington, DC, January 2027 (accepted for presentation).

Tsai, Y.-C., **Wang, H.**, & Luo, S. (2026). A problem-solving systems approach to AI education. Poster, *ASEE Annual Conference & Exposition*, Charlotte, NC, June 2026.

Wang, H.‡, Yang, Z., Tsai, Y.-C., & Huft, D. (2026). A structurally defined crack density indicator based on a Crack Vector Model (CVM). *Road Profile Users' Group (RPUG) Annual Conference*, Pittsburgh, PA, April 2026.

Wang, H.‡, Yang, Z., Tsai, Y.-C., & Moriarty, J. (2026). Evaluating cracking data quality using field-labeled crack map ground reference. *RPUG Annual Conference*, Pittsburgh, PA, April 2026.

Yang, Z., **Wang, H.**, Tsai, Y.-C., & Miller, R. (2026). A three-level cracking definition framework for consistent and flexible pavement crack reporting. *RPUG Annual Conference*, Pittsburgh, PA, April 2026.

Wang, H.‡, Yang, Z., Geary, G. M., & Tsai, Y.-C. (2026). Standardizing cracking data quality assessment and quantification: Case studies in Florida, Mississippi, and Texas. Poster, *Transportation Research Board 105th Annual Meeting*, Washington, DC, January 2026.

Zhang, X., **Wang, H.**‡, & Yang, Z. (2026). Towards successful implementation of automated raveling detection: Effects of training data size, illumination difference, and spatial shift. Poster, *Transportation Research Board 105th Annual Meeting*, Washington, DC, January 2026.

Wang, H.‡, & Tsai, Y.-C. (2025). Toward reliable pavement digital twins: Multi-scale spatiotemporal monitoring challenges and solutions. *1st ACM SIGSPATIAL International Workshop on Spatial Digital Twins*, November 2025.

Yang, Z., **Wang, H.**‡, Salameh, R., Mohammadi, M., & Tsai, Y.-C. (2025). Cracking data quality assessment using ground references: Developing a standard methodology. *RPUG Annual Conference*, April 2025.

Wang, H.‡, Yang, Z., Salameh, R., Mohammadi, M., & Tsai, Y.-C. (2025). Impact analysis of image offsets on time-series crack analysis variability using 3D pavement imaging data. Lectern session, *Transportation Research Board 104th Annual Meeting*, Washington, DC, January 2025.

Wang, H.‡, Yang, Z., Mohammadi, M., & Tsai, Y.-C. (2024). Deformable registration on pavement images for topological crack propagation analysis. Poster, *Transportation Research Board 103rd Annual Meeting*, Washington, DC, January 2024.

Yang, Z., Mohammadi, M., **Wang, H.**, & Tsai, Y.-C. (2024). A feature-based pavement image registration method for precise pavement deterioration monitoring. Poster, *Transportation Research Board 103rd Annual Meeting*, Washington, DC, January 2024.

Tsai, Y.-C., Yang, Z., **Wang, H.**, & Mohammadi, M. (2024). Multi-temporal pavement image registration for pavement distress deterioration analysis. *TRB Pavement Analysis Workshop (PAWS)*, 103rd Annual Meeting, Washington, DC, January 2024.

Wang, H.‡, & Tsai, Y.-C. (2023). Machine learning with microtexture feature extraction for automated pavement raveling classification. *ASCE Engineering Mechanics Institute Conference (EMI 2023)*, Atlanta, GA, June 2023.

PATENTS

Nondestructive crack monitoring method for ballastless track slabs. China National Intellectual Property Administration, CN202010987184.0 (granted 2020).

Nondestructive testing method for ballastless track slabs in rail transit. China National Intellectual Property Administration, CN202010985244.5 (granted 2020).

TEACHING EXPERIENCE

School of Civil and Environmental Engineering, Georgia Institute of Technology

Head Teaching Assistant, CEE 3090 Data Analytics in Civil & Environmental Engineering Fall 2026

- Deliver lectures on tree-based methods, deep learning, and survival analysis; lead the Python lab sequence (environment setup through regression, classification, cross-validation, and model selection).

- Designed the five-lab Python curriculum from the ground up (student notebooks, instructor keys, and slide decks) with real civil-engineering datasets (EPA PM2.5 monitors, UCI concrete strength, FHWA LTPP pavement sections, the full Georgia National Bridge Inventory), including a deliberate observational-confounding lesson that prepares students for the course project.
- Co-developed the midterm and the term project; coordinate the TA team, assign responsibilities, and review student analyses and code with written feedback.

Teaching Assistant, CEE 4803 AI for Smart Cities — Spring 2024, Spring 2025

- Delivered lectures and Python lab instruction; designed assignments and grading rubrics for an applied-AI course serving undergraduates and graduate students.

Teaching Assistant, CEE 8813 Data Analytics for Transportation Safety (graduate) — Fall 2024

- Developed and graded Python/GIS crash-analytics assignments; mentored term-project teams.

Teaching Assistant, CEE 4803 Data Analytics in Civil & Environmental Engineering — Fall 2023, Fall 2024

- Designed assignments and supported lectures in the course that became CEE 3090.

Recognition: CEE Bill Schutz Graduate Teaching Assistant Award, Georgia Tech (2025); nominated for the Institute-wide Outstanding Graduate Teaching Assistant Award.

Teaching interests: data analytics and machine learning for civil engineering; infrastructure sensing and condition assessment; pavement engineering and asset management; digital twins and spatiotemporal data; optimization and automation for infrastructure maintenance; programming and reproducible research for engineers.

RESEARCH MENTORING

Graduate Mentor, Vertically Integrated Projects (VIP) Program, Georgia Tech — Spring 2023 – Present

- Supervise undergraduate and graduate teams on semester-long research sub-tasks: crack-definition standardization, 3D spatiotemporal pavement and raveling analysis, image registration, lane-marking annotation, and LiDAR-aided sidewalk assessment; define scopes, run weekly check-ins, and review deliverables.
- Mentored student researchers including Sooha Ryu, Jordan Fung, Jiao Bao, and Trinh Flynt; mentees are co-authors on the CRASDI, crack-density, and deformable-registration manuscripts.

HONORS & AWARDS

CEE Bill Schutz Graduate Teaching Assistant Award, Georgia Tech — 2025

Excellent Graduate, Tongji University — 2021

First Prize, Tongji Scholarship for Excellent Students — 2020

Bronze Award, Fifth “Excellence Cup” Competition, Tongji University — 2020

Third Prize, Shanghai University Student Computer Application Ability Competition (Mini Traffic urban-road simulator, team lead) — 2019

Excellent Student Leader, Tongji University — 2018 & 2019

PROFESSIONAL SERVICE

Peer review

- Reviewer, *ASCE Journal of Computing in Civil Engineering*: 16 reviews (10 manuscripts including revisions), 2024 – present.
- Reviewer, *Transportation Research Record*: 2 reviews, 2026.
- Reviewer, TRB Annual Meeting: 6 papers (2026 and 2027 meetings).

Project and community

- Core team member, NCHRP Project 01-57B; presenter to the project panel and at the Road Profile Users’ Group (2025, 2026).

TECHNICAL SKILLS

Software: Python, SQL, MATLAB, ArcGIS, Git/GitHub; open-source packaging and reproducible research pipelines.

Languages: English (fluent), Mandarin Chinese (native).