AN AI-POWERED AERIAL NAVIGATION SYSTEM FOR DYNAMIC ACCESSIBILITY AWARE PATHFINDING

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Zahra Derakhshandeh

Dr. Zahra Derakhshandeh is an Associate Professor in the Department of Computer Science at California State University, East Bay. She earned her Ph.D. in Computer Science from the School of Computing, Informatics, and Decision Systems Engineering at Arizona State University in August 2017. Her research focuses on Distributed Computing, Algorithm Design and Optimization, and AI-assisted Robotics, Bio-inspired Algorithms, and Programmable Matter. She is interested in the algorithmic foundations of Self-Organizing Particle Systems (SOPS), exploring how distributed, programmable agents can collectively solve complex problems through local interactions and emergent behavior. Her work also extends to AI-assisted robotics, including unmanned aerial vehicles (UAVs) and intelligent robotic systems, integrating machine learning and artificial intelligence for adaptive coordination, autonomous navigation, and decision-making. She is also engaged in active learning and AI-driven educational initiatives, utilizing intelligent systems and adaptive technologies to enhance student learning and engagement in computing and STEM education.

Ayushi Dwivedi

Ayushi received her masters in computer science from California State University, East Bay in 2024. She is currently working as a Data Engineer at Visa, India.

Her research interests lie in Artificial Intelligence and Distributed Systems, with a focus on developing scalable data-driven solutions.

Problem

- 1/4 adults in United States have disabilities and 12.1% have mobility issues
- 96% Participants of the survey with mobility limitations conduct research before visiting locations to obtain information, both about the planned route and the accessibility of the location.[11]
- Research shows 63% participants of a survey suffer with vague and outdated information despite conducting prior research.[11]

Existing Research Landscape

Accessibility Gaps: Many studies emphasize challenges faced by people with disabilities in indoor environments, including poor signage, inconsistent digital-physical mapping, and high cognitive load
during navigation.
Focus on Visual Impairments: Most prior work focuses on blind or visually impaired users, overlooking the distinct needs of mobility- impaired individuals.

Related Work

Mobile & Assistive Technologies

- Smartphone-based systems using Wi-Fi localization and pre-mapped accessibility data help guide users indoors ([2]).
  Limitation: Works well in static environments but lacks real-time perception and dynamic path adaptation.
- Simulation frameworks ([3]) assist in design-time evaluation of indoor accessibility.
  Limitation: Do not provide in-the-moment navigation for users.
- Static map-based solutions ([4][5]) fail to handle dynamic environmental changes such as temporary obstacles, construction, or crowding.

Related Work

Computer Vision & Deep Learning Approaches

- Deep learning and machine vision applied for hazard detection and pedestrian tracking ([6][7]).
  Strength: Promising for real-time perception.
  Limitation: Focus mainly on outdoor environments or visually impaired users, not mobility-related challenges indoors.

Related Work

Drone-Based Assistance – An Emerging Field

- Drones show potential in infrastructure inspection, emergency response, and now assistive navigation.
- Global drone market projected to grow from $15.9B (2023) to $53.4B (2030) making real-time navigation tech (object detection, obstacle avoidance) more accessible.
  Existing drone research:
- Drones assist visually impaired users via auditory cues and airflow, following pre-recorded paths[8] .
- Wearable fall detectors + drones deliver emergency aid autonomously [9].
- Integration of VR with drones enables immersive experiences for users with limited mobility[10].

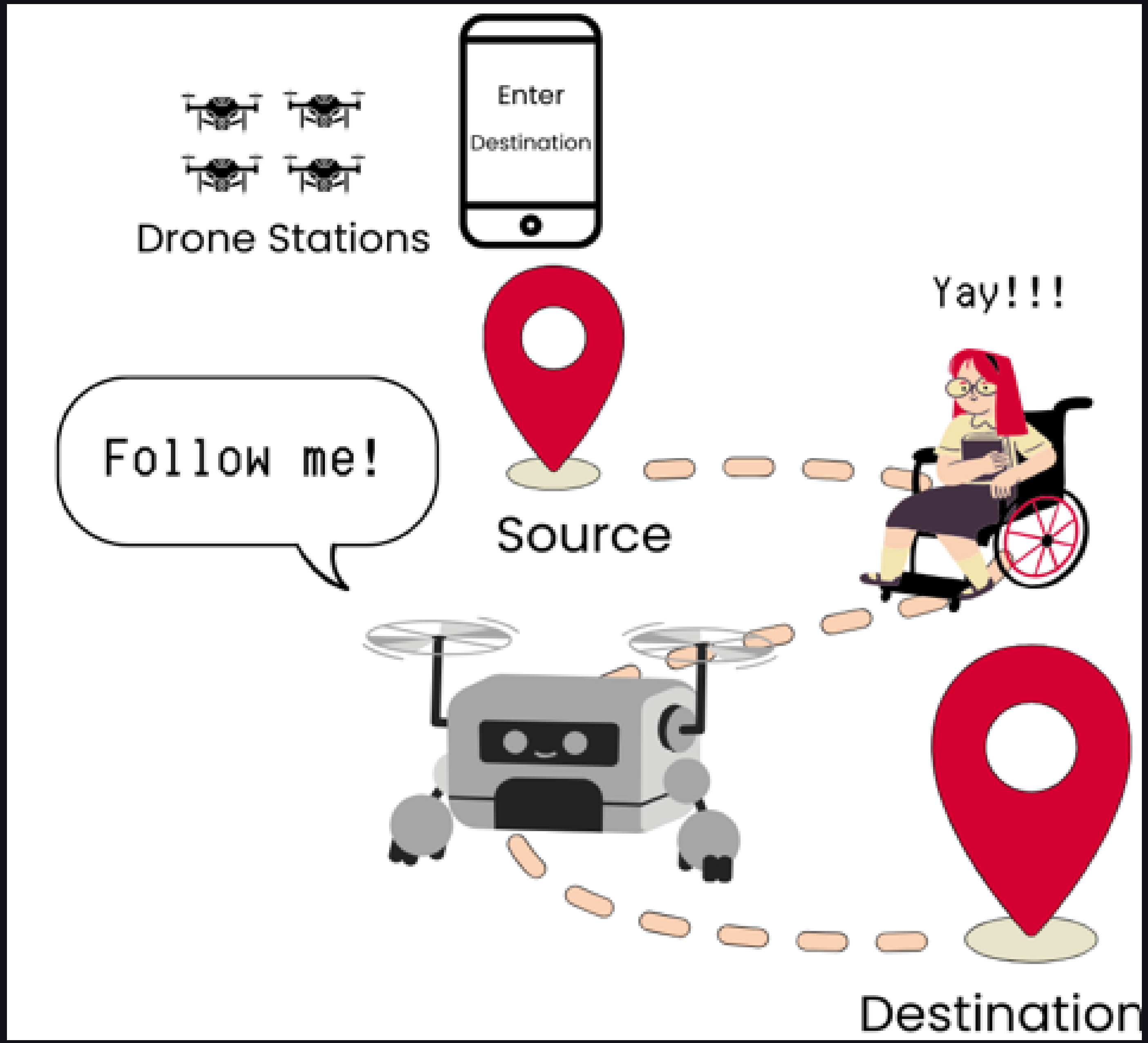
FOR A DETAILED REVIEW AND RELATED WORK, PLEASE SEE THE FULL PAPER.

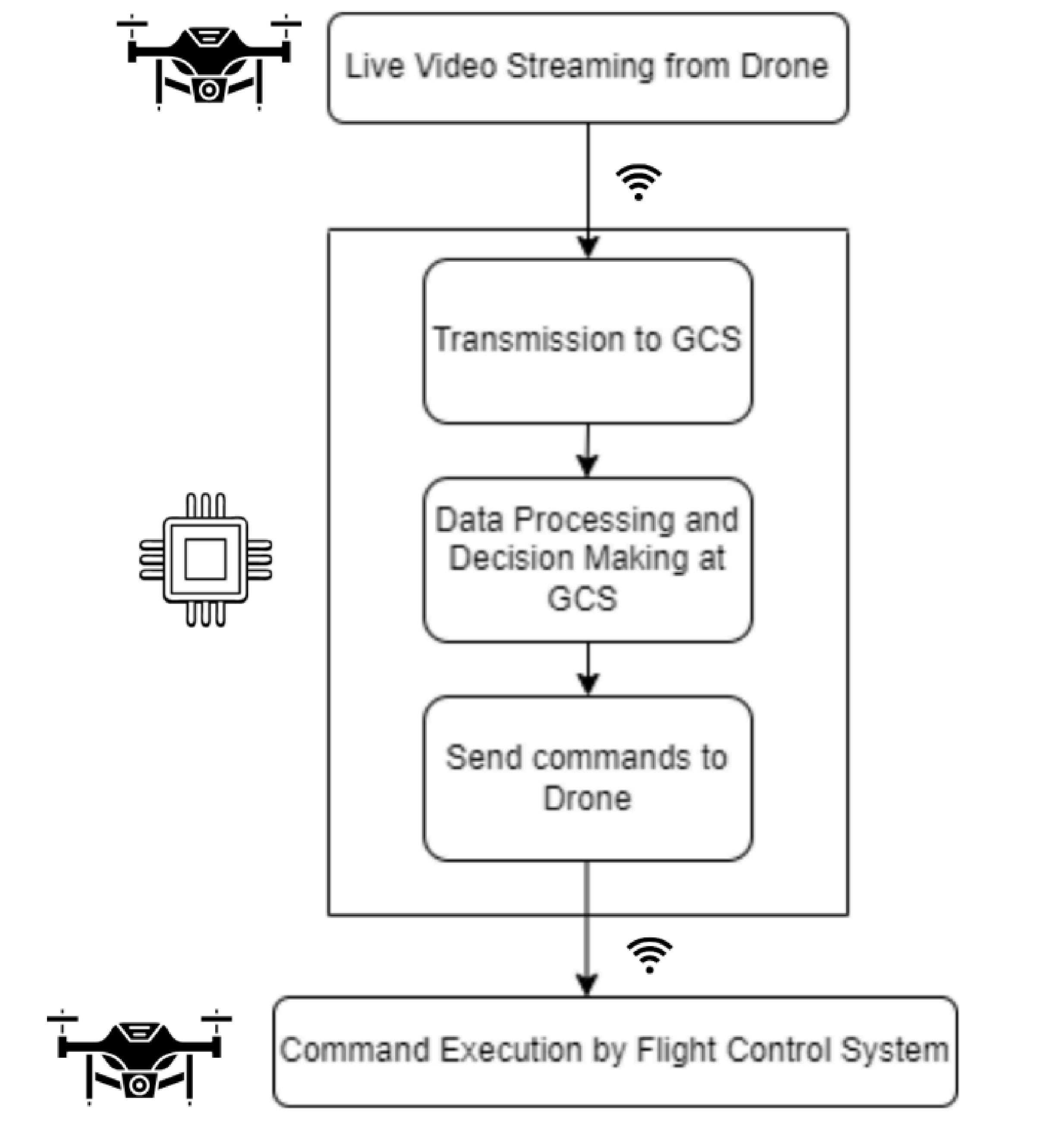
Research Gap Identified

- Current systems lack real-time, adaptive indoor navigation tailored for mobility-impaired individuals.
- There is an opportunity to explore AI-powered drones as dynamic assistive agents capable of perceiving, reasoning, and guiding users in changing indoor environments.

Solution

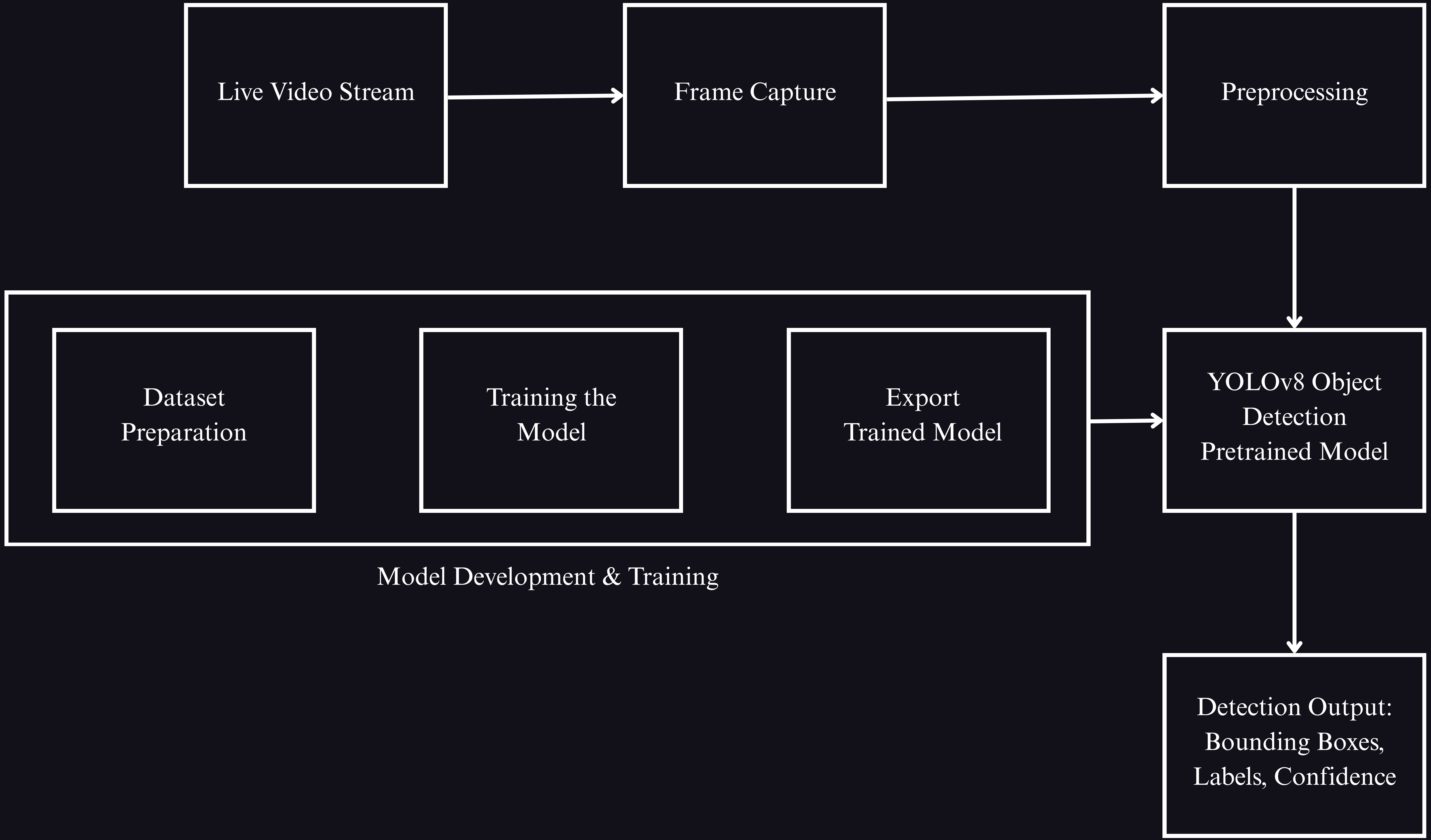
- Drone based navigation guide to help people with limited mobility reach their destination
- Enhances independence and inclusivity





- DJI Robomaster TT Drone establish a Wi-Fi connection with the Ground Control System (GCS)
- Live streams will be transmitted to the GCS
- The GCS will send commands to drone

System Architecture



WORKFLOW OF THE YOLO OBJECT DETECTION PIPELINE USED IN THE PROPOSED DRONE-BASED NAVIGATION SYSTEM. THE GCS RECEIVES LIVE VIDEO STREAMS FROM THE DRONE AND PROCESSES EACH FRAME USING THE PRE-TRAINED YOLO MODEL [1].

DYNAMIC PATH NAVIGATION ALGORITHM

- Constructs an accessibility-compliant graph representing the environment.
- Computes the shortest path from source to destination using Dijkstra's algorithm.
- Continuously monitors for obstacles during navigation.
- If an obstacle is detected, removes the blocked edge and recomputes the path dynamically.
- Guides the drone safely until it reaches the destination.

THEOREM 1

The worst-case runtime of our Dynamic Path Navigation algorithm is $O(E \cdot (|V| + |E|) \log |V|)$ in the worst case.

THEOREM 2

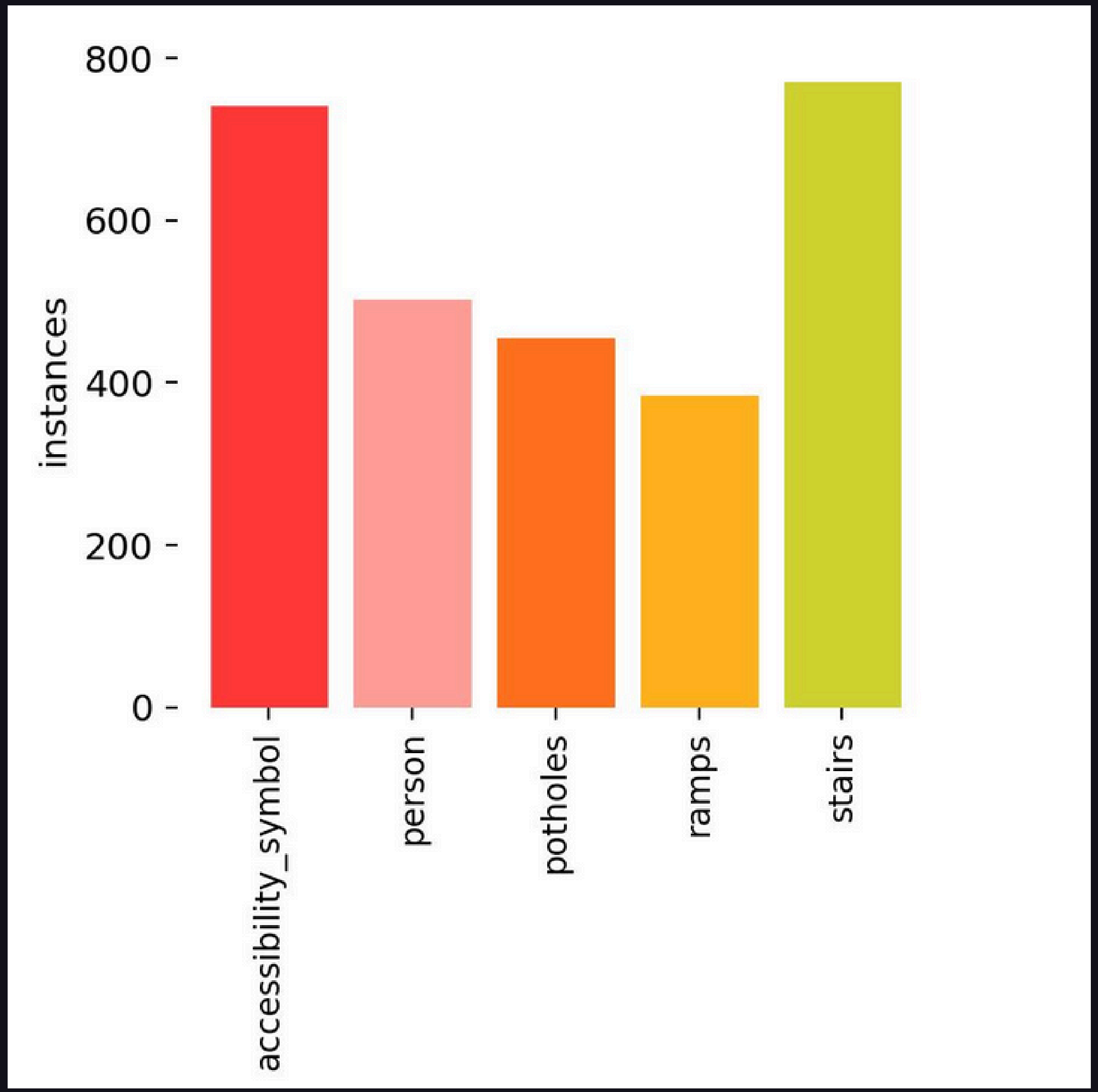
If there exists at least one unblocked path from the source node s to the destination d at any time during execution, then the Dynamic Path Navigation Algorithm will reach d in finite time.

These theorems summarize the computational efficiency and completeness guarantees of the proposed algorithm. Formal proofs are omitted for brevity but can be found in the extended version of this work.

ACCESSIBILITY-ORIENTED OBJECT DETECTION USING DRONES

Data Collection and Annotation

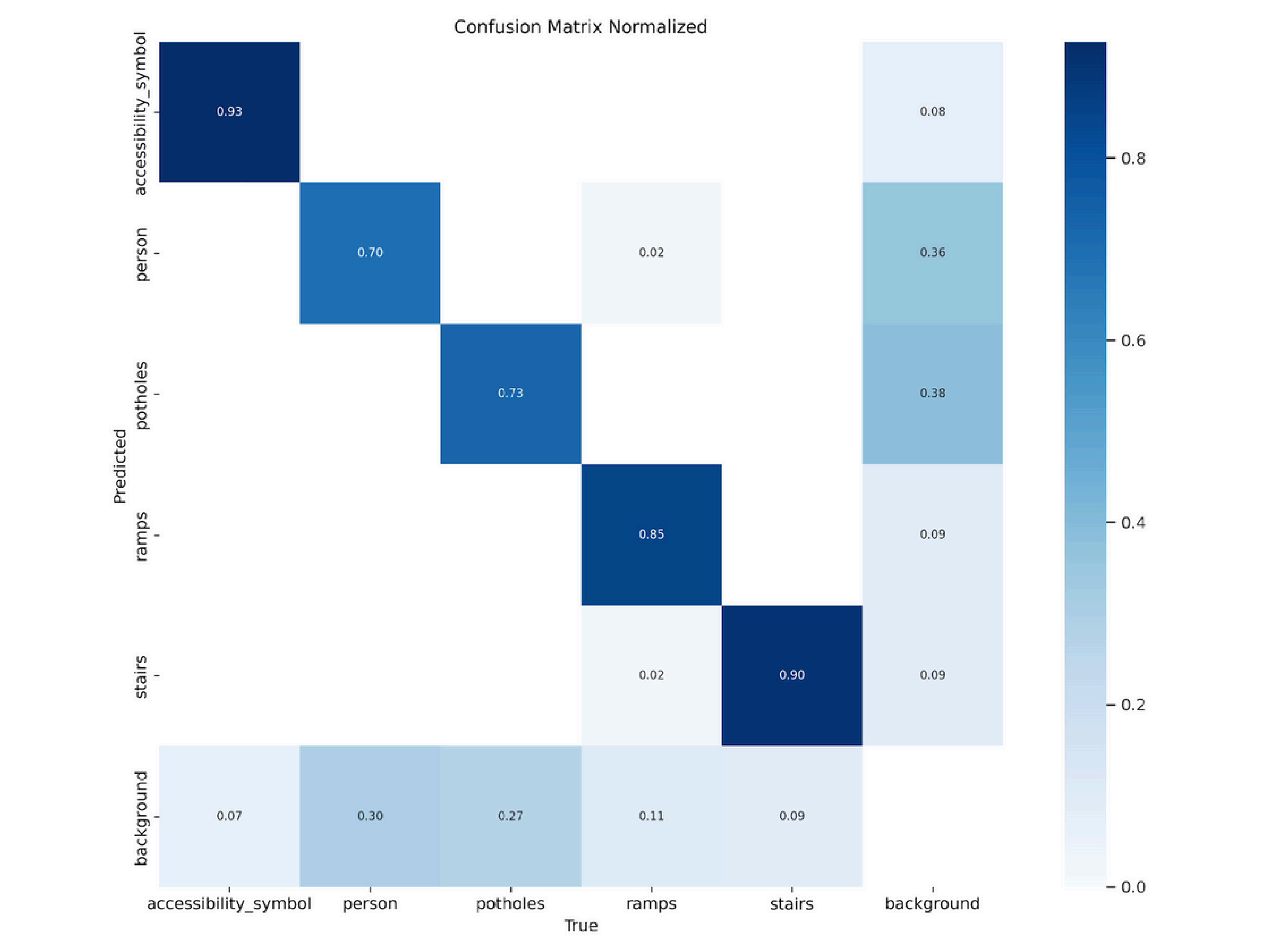
- Collected 4500+ images containing ramps,stairs,potholes,people and accessibility symbol
- Used roboflow for annotation



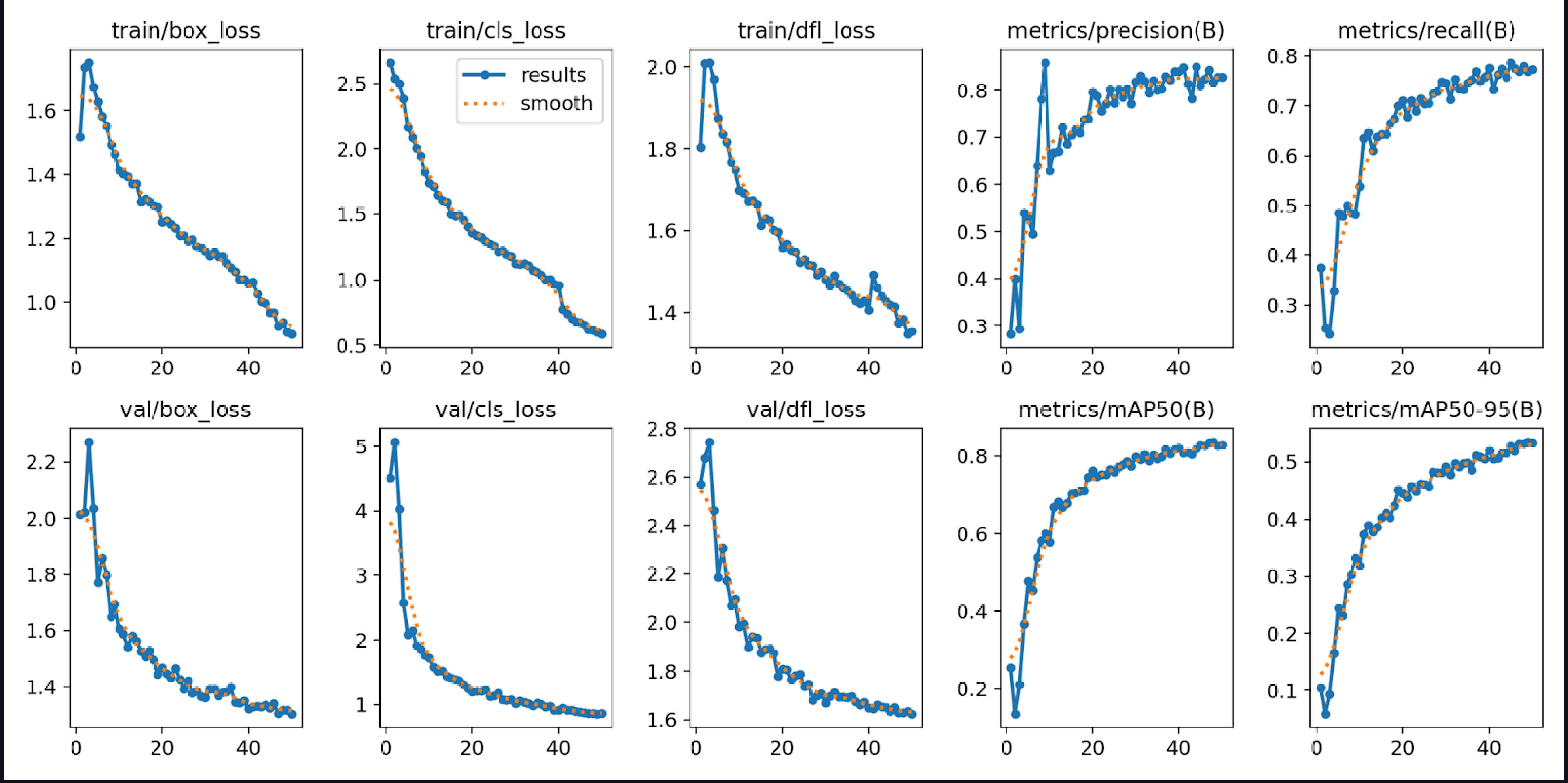
ACCESSIBILITY-ORIENTED OBJECT DETECTION USING DRONES

Model Evaluation Metrics

- The model performs best in predicting accessibility symbols (93% accuracy) and stairs (90% accuracy)



ACCESSIBILITY-ORIENTED OBJECT DETECTION USING DRONES



- mAP@50 Reaching to 0.8: This high mean average precision at 50% IoU (Intersection over Union) is a strong indicator of the model's overall accuracy in object detection.

Conclusion

Experimental evaluations conducted in a controlled setting demonstrate the system's feasibility and potential to address critical gaps left by traditional, static navigation tools. The findings showcase the critical role that aerial robotics can play in improving independent mobility, reducing navigational barriers, and advancing inclusion within built environments.

Future Work

- Enhance the object detection model's accuracy and adaptability across diverse indoor environments.
- Improve dataset relevance and reduce biases.
- Conduct real-world testing in varied indoor settings to evaluate performance and safety.
- Explore integration with smart building systems and IoT sensors for scalable, inclusive deployment.

Citations

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PLEASE SEE THE FULL PAPER FOR ADDITIONAL REFERENCES.

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THANK YOU!

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