A community initiative, anchored by

INTERNATIONAL INSTITUTE OF INFORMATION TECHNOLOGY
HYDERABAD

TechForward DISPATCH

OCTOBER EDITION

TECH ENABLED SUSTAINABLE MOBILITY

Advanced technologies can create more environmentally friendly efficient transportation systems. This includes electric vehicles (EVs), autonomous transport, and smart infrastructure that optimize traffic flow. IoT sensors and data analytics can help improve the performance and energy efficiency of transportation networks. Ultimately, these innovations aim to reduce carbon emissions, lower energy consumption, and enhance urban mobility.

IIITH's TechForward research seminar series is an academia-industry confluence around emerging technologies. The deep insights, directional talks and industry outlooks from accomplished thought leaders at the seminar are compiled monthly in the Tech Dispatch as a ready reckoner for technology directions.

From the Chair's Desk

It was a pleasure to chair the October edition of the TechForward Research Seminar Series focused on Tech-Enabled Sustainable Mobility. This series stands as a collaborative platform, bridging industry and academia to spark conversations that drive impactful, innovative solutions. This month's theme is particularly relevant, as it aligns with Bosch's vision to create technology that not only moves people but also preserves the planet. Bringing together thought leaders, researchers, and innovators, this seminar allowed us to explore the latest advancements and research that can make sustainable mobility a reality.

Tech-Enabled Sustainable Mobility is about leveraging cutting-edge technology to redefine how we approach transportation in an eco-conscious way. From reducing carbon emissions and enhancing energy efficiency to extending the lifecycle of materials and embracing renewable energy sources, the aim is to make mobility smarter, cleaner, and more inclusive.

This theme resonates with Bosch's core commitment to sustainability and our motto, "Invented for life." By integrating emerging technologies like AI, IoT, and advanced robotics into mobility solutions, we can help shape a future where transportation is not only efficient and accessible but also environmentally responsible. This session was an inspiring opportunity to connect with like-minded individuals who are passionate about making sustainable mobility a reality.

AMJAD KHAN PATAN
Vice President and Centre Head of Bosch Global Software Technologies Hyderabad

CONTENTS OF THIS EDITION

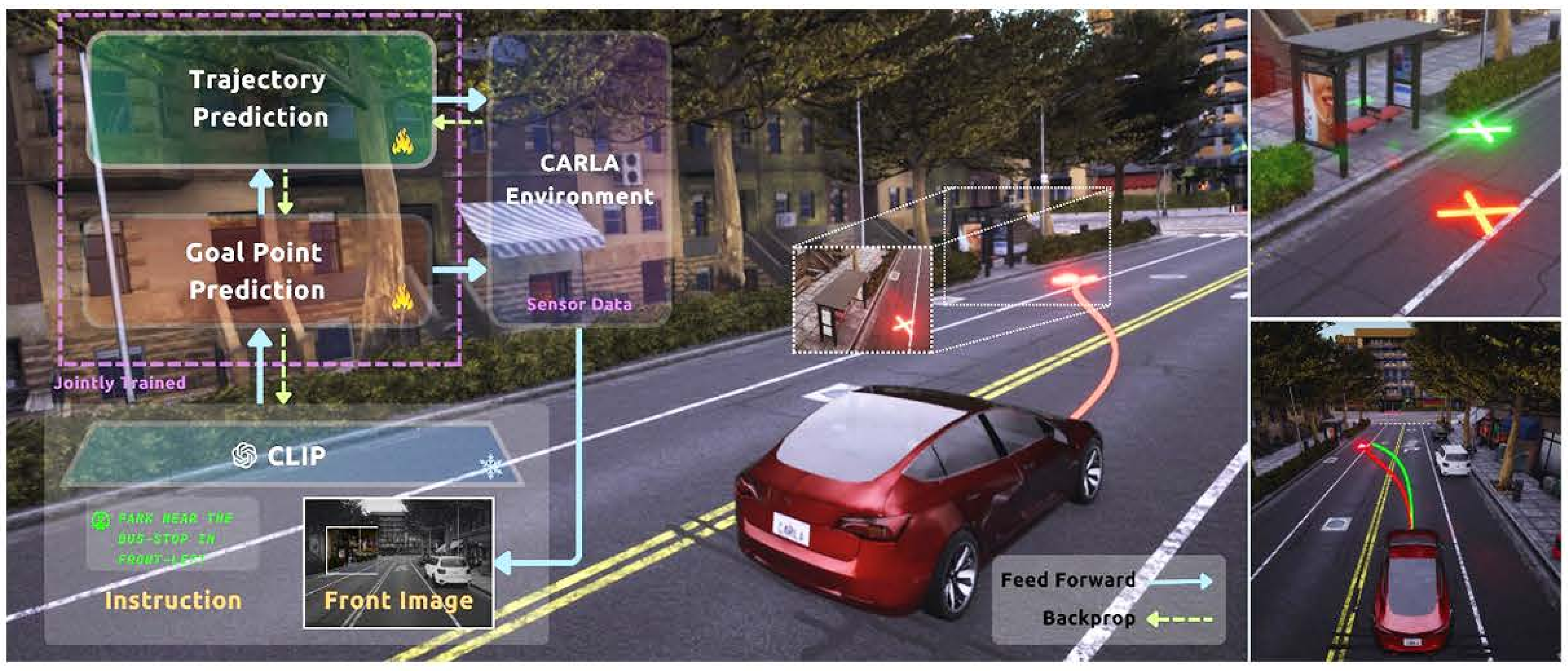
The fifth edition of TechForward was hosted at Bosch Hyderabad office.

When Modern AI Meets Classical Robotics

***Prof. Madhava Krishna** briefly explains the way IIITH's self-driving car works and what is novel about it. This is an edited excerpt from the TechForward research seminar series.*

IIIT Hyderabad's Self Driving Car is an electric vehicle that performs point to point Autonomous Driving with collision avoidance capabilities over a wide area. Equipped with 3D LIDAR, Depth Cameras, GPS systems and AHRS (Attitude and Heading Reference System which essentially means sensors on three axes to estimate it's orientation in space), the car can also accept Open Set Natural Language commands and follow those commands to reach a desired destination. SLAM-based point cloud mapping is used to map the campus environment and a LIDAR-guided real-time state estimation allows for localization while driving. Trajectory optimization frameworks a-la Model Predictive Control provides for real-time rollout of optimal trajectories. Such trajectories can be initialised with data-driven models for faster inference time optimization. A number of publications in high-profile venues and highly competitive conferences decorate the research landscape of Autonomous Driving research at the International Institute of Information Technology, Hyderabad, Gachibowli Campus.

Open Set Navigation



To better understand open set navigation commands, let's first consider how humans often navigate - with minimal map usage, relying on contextual cues and verbal instructions. Many navigation directions are exchanged based on recognizing specific environmental landmarks or features, for example, "Take right next to the white building" or "Drop off near the entrance". In a parallel context, autonomous driving agents need precise knowledge of their pose (or localization) within the environment for effective navigation. These are typically achieved using high-resolution GPS or pre-built High-Definition (HD) Maps like Point Cloud, which are compute and memory-intensive.

Alternatively, many efforts utilise open-source topological maps (GPS-like Maps) for geolocalization, like OpenStreetMaps (OSM), as a lightweight solution. However, they are metrically inaccurate (~6-8 meters) and suffer localization errors when navigating to arbitrary destinations within the map. Moreover, some environmental landmarks, such as open parking spaces, may not be marked in OSM maps due to their dynamic nature. Thus, at IIITH, we are interested in exploring a feasible and scalable method to localise using solely real-world landmarks, akin to human navigation.

IIITH's Efforts

We intend to address it by exploiting foundational models that have a generic semantic understanding of the world which can be distilled for downstream localization and navigation tasks. This has been achieved by augmenting open-source topological maps (like OSM) with language landmarks, such as "a bench", "an underpass", "football field", etc. which resemble the cognitive localization process employed by humans. These enable an "open-vocabulary" nature that allows navigation to places for which the model is not explicitly trained, leading to a zero-shot generalisation to new scenes. The RRC Autonomous Driving group- AutoDP at IIITH demonstrates an attempt to integrate classical methods with post-modern solutions in open-world understanding, bringing the best of both worlds to solve the ever-challenging task of precise localization and navigation with real-world deployment through the in-house developed prototype.

Differential Planning

Mapping, localization, and planning form the key components in the Autonomous Navigation Stack. While both the modular pipeline and end-to-end architectures have been the traditional driving paradigms, the integration of language modality is slowly becoming a defacto approach to enhance the explainability of autonomous driving systems. A natural extension of these systems in the vision-language context is their ability to follow navigation instructions given in natural language – for example, "Take a right turn and stop near the food stall." The primary objective is to ensure reliable collision-free planning. Traditionally, upstream predictions and perception are customised for improving the downstream tasks, which is typical in current Vision-Language-Action models and other existing end-to-end architectures. However, prediction and perception components are often tuned with their own objectives, rather than the overall navigation goal. In such a pipeline, the planning module heavily depends on the perception abilities of these models, making them vulnerable to prediction errors. Thus, end-to-end training with downstream planning tasks becomes crucial, ensuring feasibility even with arbitrary predictions from upstream perception and prediction components.

Our USP: NLP+VLM

To achieve this capability, IIITH has developed a lightweight vision-language model that combines visual scene understanding with natural language processing. The model processes the vehicle's perspective view alongside encoded language commands to predict goal locations in one-shot. However, these predictions can sometimes conflict with real-world constraints. For example, when instructed to "park behind the red car," the system might suggest a location in a non-road area or overlapping with the red car itself. To overcome this challenge, we augment the perception module with a custom planner within a neural network framework. This requires the planner to be differentiable, enabling gradient flow throughout the entire architecture during training which eventually improves both prediction accuracy and the planning quality. This end-to-end training approach with a differentiable planner serves as the key sauce of our work.

PROF. MADHAVA KRISHNA

IIIT HYDERABAD

is Professor and Head of the Robotics Research Centre and the Kohli Center for Intelligent Systems (KCIS) at IIITH.

How Collaboration Can Accelerate Sustainability Of The Mobility Sector

Anand Narayanan shared a compelling industry perspective on the evolving landscape of "Tech-Enabled Sustainable Mobility" and the pressing need for sustainable solutions in the mobility sector.

BGSW Hyderabad, in collaboration with IIIT Hyderabad, co-hosted the fifth edition of the TechForward: Research Seminar Series, centered on the theme of "Tech-Enabled Sustainable Mobility." The session brought together speakers from industry and academia, including Prof. K. Madhava Krishna from IIIT Hyderabad, who shared valuable insights on Multi-Modal Localization and Navigation. Bosch's Anand Narayanan provided an industry perspective, discussing innovative strategies for achieving sustainable mobility. The event was attended by participants from diverse backgrounds, including industry leaders, academia, and startups, fostering a vibrant exchange of ideas and collaborative opportunities.

Anand highlighted the critical role of the ecosystem in driving the market, emphasising how government policies and the societal push toward sustainable practices are accelerating this shift. He pointed out that consumer experience (CX) remains a priority, but there is a need to balance it with sustainable initiatives. For example, while the h rising demand. adoption of electric vehicles (EVs) is growing, it still faces challenges like limited infrastructure, with charging stations struggling to keep up wit

Initiatives At Bosch

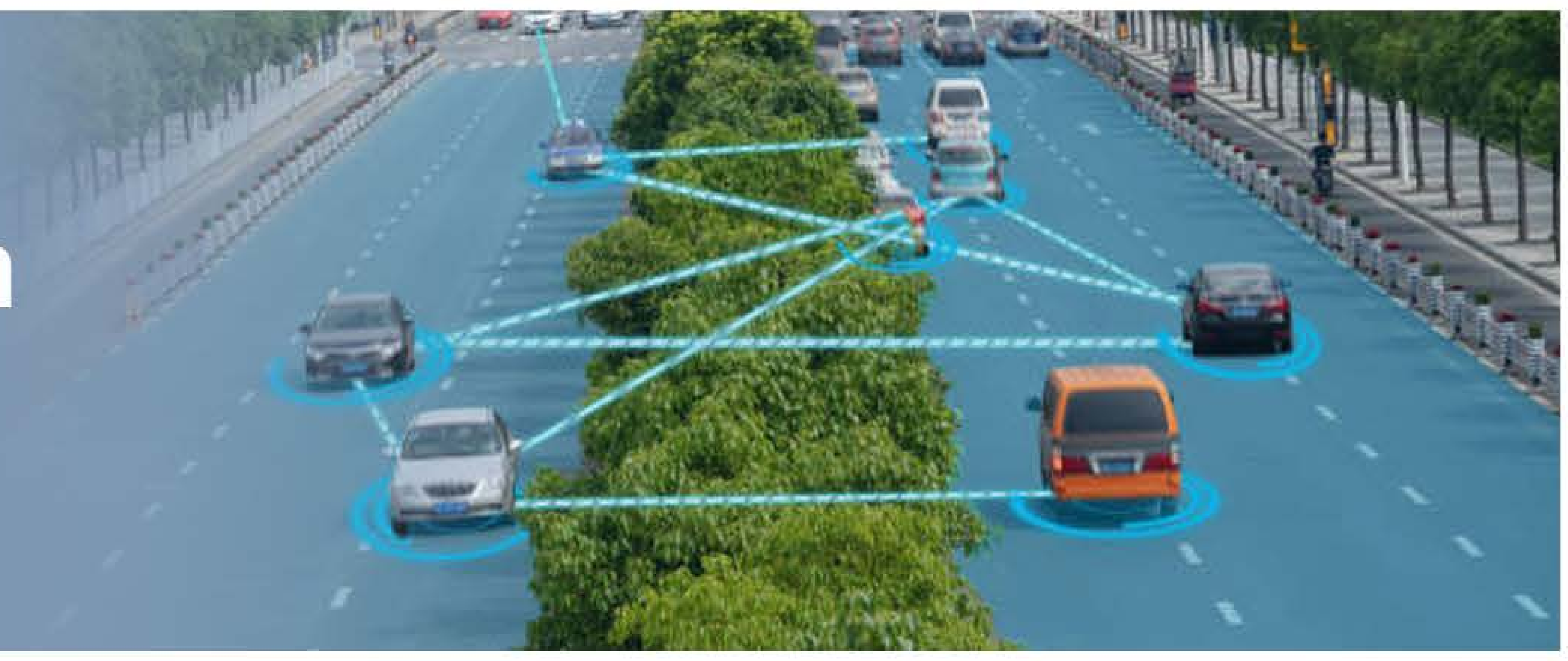
Anand discussed the various technologies underpinning sustainable mobility, including Battery Management Systems (BMS), energy storage solutions, and advancements in vehicle control units. He stressed the importance of Electrical and Electronic (E&E) architecture, which enables energy optimization and allows vehicles to self-diagnose and improve performance. Bosch is actively working on Vehicle-to-Everything (V2X) connectivity, which facilitates communication between vehicles and their environment, contributing to safer, more efficient transportation. In terms of Bosch's contributions, Anand highlighted that Bosch campuses are now 100% powered by green energy, with significant efforts toward water neutrality and waste management. The company's commitment to reducing CO_2 emissions aligns with its larger vision for climate action and circular economy practices.

Multi-sector Partnerships

Anand also stressed the importance of an integrated approach that involves collaboration across industry, government, and academia. He emphasised that sustainable mobility solutions must be holistic, involving advancements not just in vehicle technology but also in infrastructure, policy, and user behaviour. This collaborative approach, he argued, will be essential for accelerating the adoption of sustainable technologies and driving meaningful change in the mobility sector.

ANAND NARAYANAN
SENIOR DIRECTOR AT BOSCH GLOBAL SOFTWARE TECHNOLOGIES

Mobility Initiatives From The IIITH Stable



***Prof. Ravi Kiran Sarvadevabhatla** lists out the various solutions developed by IIITH for the Indian mobility sector.*

The impact of AI on our daily lives is manifold. Technological innovations are disrupting various industries too, from education and healthcare to manufacturing and transportation, to name a few. In the field of transportation, self-driving cars have particularly gripped everyone's imagination. But the mobility ecosystem has expanded over the last few years to go beyond autonomous navigation. The i-Hub-Data centre located on IIITH campus has been actively involved in various applications that are multi-disciplinary in nature for mobility-based problems.

One of them concerns detecting abnormal traffic patterns and rule violations on Indian roads. These include traffic violations by two wheelers such as riding without a helmet, triple riding, wrong side driving, and others. The traditional approach for tackling these problems has been to use CCTV cameras that are mounted on traffic lights and at intersections. The cameras capture videos which are then analyzed to detect violations. The data of the violation is transferred to a centralised server at the Traffic Control Room where a challan is generated. This system however has certain limitations; the chief being that the violators know exactly where the cameras are since the cameras are fixed. The element of surprise is missing here. In order for deterrence to be a key strategy that leads to a better adherence to traffic rules, then it is important that there be an element of surprise.

Leveraging Bodhyaan

A decision was taken to leverage Bodhyaan - an advanced multimodal research vehicle which is equipped with multiple sensors and helps in capturing traffic data. With this data, Bodhyaan enables research from academia and the Indian startup industry to work on specific problems pertaining to Indian traffic and roads. In order to overcome the limitations of static CCTV cameras, we developed a complete pipeline that captures videos of traffic violations via Bodhyaan and tags them under various violation categories. With these video clippings available at the police control room, it is easy to draw up challans.

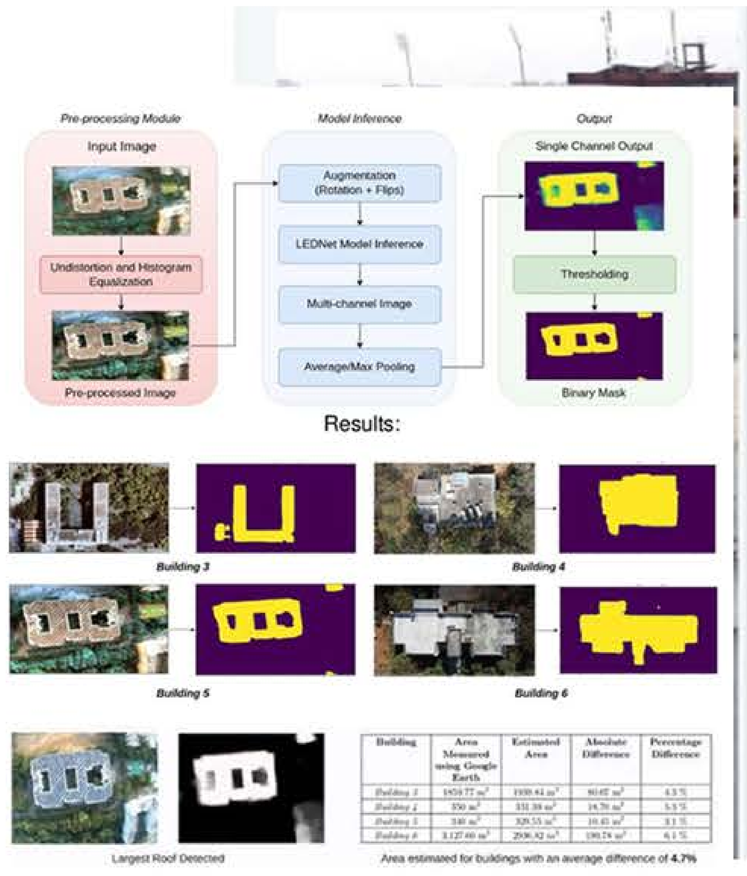
Data Collection At Scale

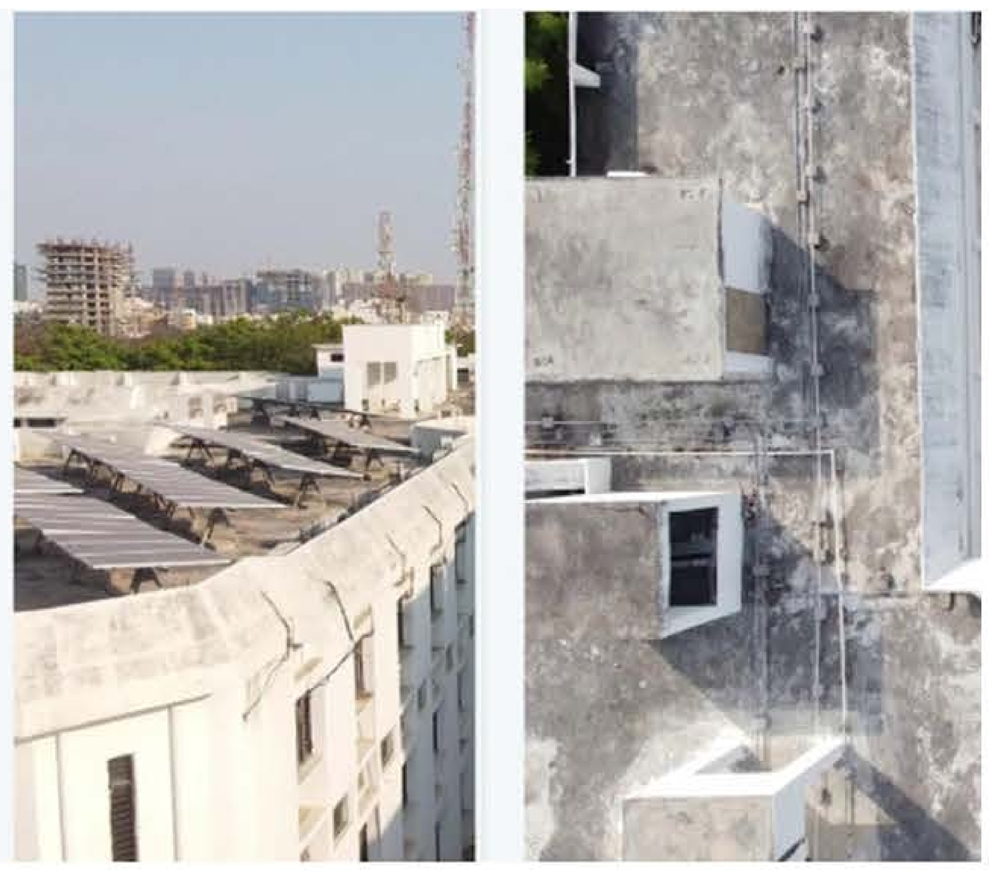
With two wheelers constituting a majority of Indian traffic and consequently a majority of traffic violations too, a similar initiative to curb wrong side driving by two-wheelers - which is a major cause of road accidents - has been undertaken. Data of traffic violations by two wheelers was captured at a fleet scale rather than via a single platform. We used video recordings captured by dashcams mounted on cabs and buses that criss-cross the city roads. The videos are processed by our system and challans generated accordingly. In this way, there is not only an element of surprise but also a distribution in the capturing of data through out the city.

Two Wheeler Platform

Just like Bodhyaan for four wheelers, there is now a two wheeler technology platform that aims to collect data encompassing every facet of two wheeler safety such as technologies that detect falls, rider alert and assistance, as well as other technologies related to accessories such as smart helmets. The intent in this case is also to measure riding behaviour and come up with riding scores. The reasoning behind this is to potentially use these scores to rank people as safe drivers. It could be used by either insurance companies or automobile dealers to incentivise safe driving practices by changing premium amounts or offering discounts respectively.

Multi-disciplinary Project





A unique drone-based infrastructure assessment project saw the joining hands of researchers from the Robotics Research Centre, the Centre for Visual Information Technology and the Earthquake Engineering Research Centre. The current method of assessing building safety involves a manual procedure where people measure various parameters of the building such as height of the building, height of each storey in the building, number of windows it has, number of heavy objects on the roof, percentage of roof area occupied by these heavy objects, and so on. We realised that some parts of the survey form could be filled out automatically. For this, we used a combination of a drone equipped with computer vision technology. The idea was to create a software package that could be used by non-technical experts too. The software takes video footage shot from the drone as input, and automatically determines the parameters that are required without any manual intervention. So what would previously take many hours of manual work can now be done in a couple of seconds with this software.

Tree Counting

Another example of a large-scale project that was undertaken in the past relates to the one commissioned by the Municipality. The local body often embarks on tree plantation drives and wanted to know how successful or how green was one such area after the drive. To arrive at the density of tree cover in a particular area, a two wheeler with a GoPro camera that was facing sideways was deployed so that it could not only capture images but also the corresponding GPS coordinates. We not only measured tree density but also developed a dashboard demonstrating tree cover for a particular geographical region. What was originally developed for inner city roads was later extended to the outer ring road area too. A similar solution was also developed to map the city's potholes which was then made available on a dashboard.

i-RASTE

One of the bigger projects that initially kicked off in the city of Nagpur and has since been extended to the state of Telangana is the Intelligent Solutions for Road Safety Through Technology and Engineering, otherwise known as i-RASTE. It aims to leverage the predictive power of AI in preventing road accidents. The purpose of the project is twofold - one, to understand driver behaviour and the second, to map potential blackspots or accident zones in the cities. ADAS or advanced driver assistance systems equipped with dash cams were installed in a fleet of Nagpur's buses which not only emitted alerts about probable collisions but also simultaneously recorded state of the city's roads along with driver behaviour. The data was then supplemented with road safety awareness sessions with the bus drivers to understand better the motivations behind their actions. This kind of technological intervention coupled with a sociological discourse led to a reduction in the number of alerts recorded by ADAS as well as accidents.

Conclusion

The i-Hub Data center which was set up under the National Mission on Interdisciplinary Cyber Physical Systems is constantly looking at ways to facilitate good, scalable solutions for a myriad of mobility-based problems. And interestingly enough, the solutions here go beyond lab prototypes. The Hub comprises of an engineering division that scales it up to be deployed in real life, thereby translating a vision into reality.

PROF. RAVI KIRAN SARVADEVABHATLA
IIIT HYDERABAD

is an Associate Professor at IIITH. Though his work is primarily in the areas of Computer Vision and applied Machine Learning, his research interests are broad-ranging with a particular predilection towards multi-disciplinary problems involving multi-modal multimedia data and disciplines.

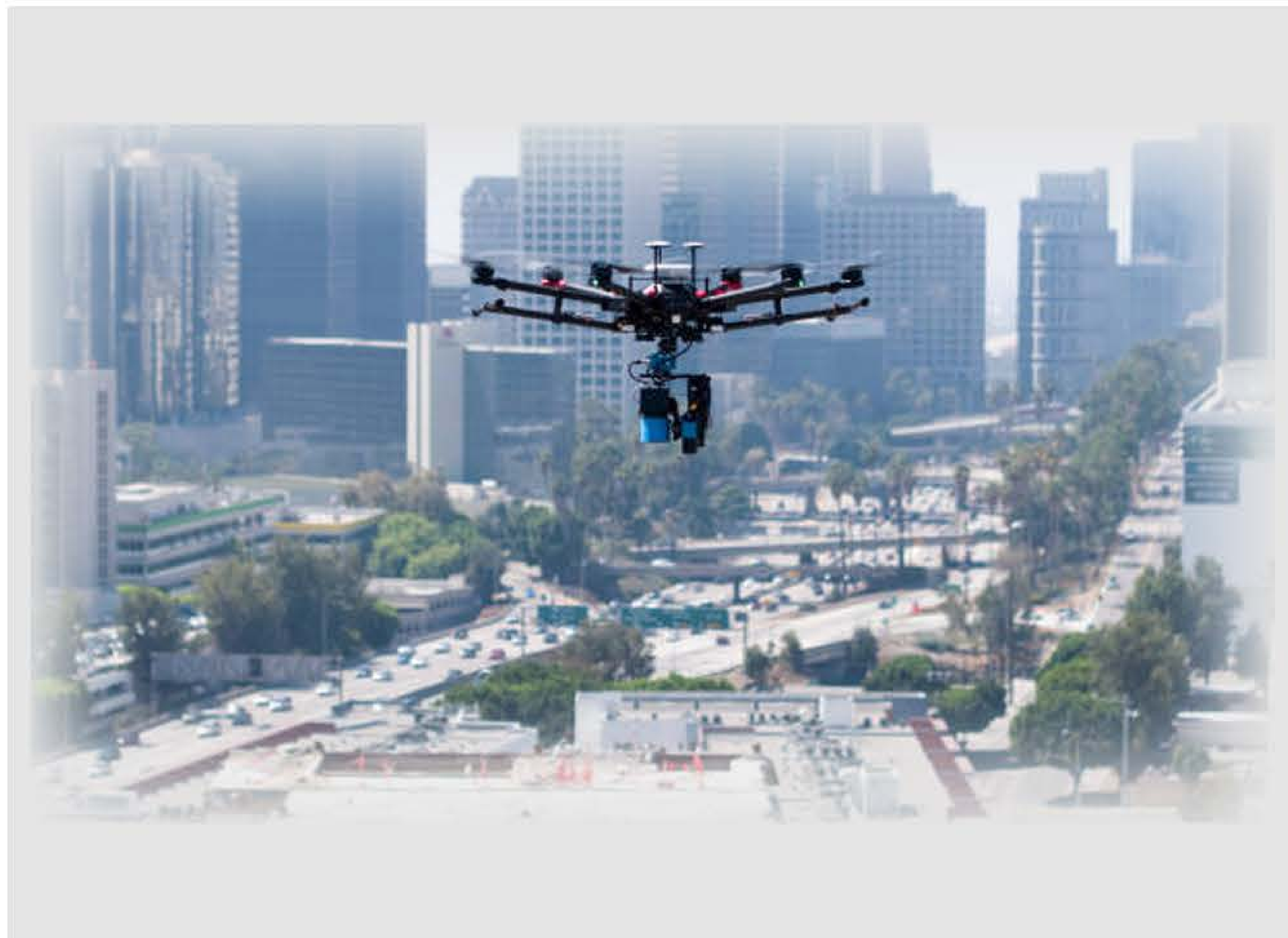
Traffic Management for Uncrewed Aerial Vehicles

***Prof. Harikumar Kandath* enumerates all that it takes for efficient traffic management of uncrewed aerial vehicles.**

By the end of this decade, the number of registered uncrewed aerial vehicles (UAVs) in India will go to a few lakhs from the present value of close to 30,000 (source DigitalSky, Govt. of India). Efficient implementation of unmanned aircraft system traffic management (UTM) will be the key to reliable, safe and scalable UAV flights. UTM services primarily include offline mission planning, online motion planning, health monitoring and flight safety system, identifying intruders and handling emergency scenarios. The offline mission planning is global and provides feasible flight trajectories for UAVs in a given airspace.

UTM Planner

The feasible trajectories should maintain the required physical separation between the UAVs. The planner should consider the types of UAV (fixed-wing/multi-rotor/hybrid-VTOL), their navigational performance, atmospheric conditions like wind speed and direction, time constraint for each UAV to complete the mission, static obstacles, and no-fly zones. The online motion planner is invoked locally when a UAV encounters either a static obstacle unknown to the offline mission planner, or a dynamic obstacle. The UAV returns to the pre-defined trajectory once the obstacle avoidance is completed.



Flight Safety

The health monitoring flags the faulty operation of the UAV sensors and actuators. The flight safety system receives inputs from the health monitoring system and takes measures like switching to redundant sensors/actuators or abrupt termination of the flight. In the case of emergency landing, a suitable landing location ought to be identified through local search and sense methods. Identifying the intruding air vehicle is primarily done using anti-UAV systems. The confirmation of intruders leads to an emergency situation that can even result in the temporary cease of flight operations.

Central Controller of UTM

A ground control station (GCS) is the central node that plans and controls the entire UTM system. The GCS should have sufficient computing capabilities to execute offline mission planning algorithms. A large database of the authorized UAVs that utilizes the given airspace along with the real-time weather information from the service provider is needed for the mission planning. A robust communication network is also necessary to monitor all the UAVs. The real-time flight data received from the UAVs has to be displayed, analyzed and stored.

Essential Hardware and Infrastructure

The primary sensors required for UAV flights are the inertial measurement unit (IMU), magnetometer, GPS, altimeter and the airspeed sensor. The obstacle avoidance requires additional sensors like LIDAR, camera, and RADAR. A companion computer to process the data from obstacle avoidance sensors and health monitoring sensors is essential apart from the main flight computer. A robust communication device is needed to transfer the real-time flight data to the GCS. Launch and landing facilities (Vertiports) are to be constructed and maintained to ensure smooth take-off and landing operations.

Risk Factors

There are multiple risk factors like network security, loss of flight stability, loss of communication, attack of intruder UAV to be considered while designing the UTM system. Compromise of network security can lead to a catastrophic situation. Loss of flight stability might result in damage to life or property. Recovery of a vehicle from unstable flight conditions using a remotely operated pilot is a daunting task. Intermittent loss of communication can be tolerated but permanent loss should result in emergency landing of the vehicle. Identifying intruder UAVs in low altitude flight regime is a challenging task. A robust anti-UAV system that can detect, identify, track, intercept and mitigate the intruder UAV is needed.

Feasibility of Large Scale UAV-based Applications

Considering the risk factors involved, the air traffic density achievable will be far less than the theoretically available space to fly. The infrastructure development and maintenance cost will be a significant factor that will determine the economic aspect of UTM-based transport. The major areas of interest would be air ambulance, medical supply delivery, and long distance transport of goods. Thus the medium (>25 Kg) and large (>150 Kg) category UAVs will be the candidates that would be preferred for these applications. The use of UAVs in densely populated cities for large scale parcel delivery seems to be far-fetched as of now.

PROF. HARIKUMAR KANDATH

IIIT HYDERABAD

Is an Assistant Professor at the Robotics Research Center, IIITH. His research focus is primarily on flight dynamics, UAV design and reinforcement learning.

A community initiative, anchored by

INTERNATIONAL INSTITUTE OF INFORMATION TECHNOLOGY
HYDERABAD

IIIT Hyderabad

TechForward
DISPATCH