Alumni's Diary

Design and Development of Autonomous UAV Configuration for Detection and Tracking of Beyond Visual Range Objects

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Introduction:
The past decade has all been about IoT and AI. Though both the concepts have a very different scope of work, researchers have been trying to unify both technologies to realize Smart systems. 'Smart' has been the new sensation of the past decade. We have been working towards, if I may say, 'Smartifying', everything in our life. Though the concepts are not new, the applications are quite novel. Using a simple wifi chip (ESP 8266 etc.) in every electronic device, we have converged our entire electronic eco-system into an App on our mobile. With IoT, we achieved control; with AI, we automated it and lost control.

Autonomous Aerial System (UAV) Design:
In this report, I will focus on smart mobility. We can conservatively estimate that every human spends 1-2 hrs per day travelling. From a global perspective, this translates to millions of man-hours per day which can be put to better use. This thought led to the idea of autonomous driving systems (ADAS). The simplest form of automatic driving we are familiar with is the auto-pilot mode used in air-crafts and cruise control mode in cars. These technologies work in a very limited set of environmental and vehicular dynamics. In both cases, the driver has to be constantly vigilant and take control of manual operation if the underlying scenarios in which the auto-pilot or cruise control are engaged have changed. For example, change in weather causes signal disruption in air-craft transponders or an increase in traffic on highways where the cruise control can no longer maintain the speed. So these methods can be considered semi-autonomous systems.

With the advent of AI, a new era of fully autonomous systems evolved where manual operations are drastically minimized. For example:, the new XUV 700 has ADAS, which automatically slows down and halts if there is any obstruction in the path, though it is set on cruise control mode. This is a significant achievement obtained by the fusion of a multitude of sensors onboard the vehicle.

Smart mobility encompasses various elements of technology and mobility. It is a novel approach towards the design and development of the transportation infrastructure used in daily life. Besides using traditional motor vehicles, electric vehicles, and public transportation systems, it also encompasses new modes of transportation like on-demand ride-sharing services (Uber and Lyft) and car-sharing programs. Changes in consumer behaviour coupled with the rise of completely new mobility options are rapidly changing how people get around. Concerns around pollution, traffic congestion, loss of productivity and (of course) money have made this idea gain traction in recent years.

Smart mobility can be broadly divided into the following sub-sets:

- Transportation Infrastructure facilitating smart mobility
- Ground and air-based traffic control algorithms
- Multi-sensor fusion on edge systems
- Information Fusion at the central node
- Autonomous systems

Each module mentioned above in itself is a huge area of research. We limit our discussion to the autonomous driving part of the smart mobility ecosystem.

The Society of Automotive Engineers (SAE) currently defines six levels of driving automation ranging from Level 0 (fully manual) to Level 5 (fully autonomous). These levels have been adopted by the U.S. Department of Transportation.

Autonomous systems are not new, but the present-day systems are far more advanced than the traditional auto-pilot systems etc. The breakthrough in machine learning algorithms on object detection, classification and localization, and natural language processing made huge strides towards the success of autonomous systems. The evolution of autonomous driving systems can be summarized as follows:

- Class 1: No Automation-The system operates under complete manual control
- Class 2: Basic Automation-The system offers basic automation like cruise control
- Class 3: Partial Automation-ADAS systems currently being used fall under this criteria
- Class 4: Conditional Automation-The system is capable of monitoring environmental conditions and performing most driving tasks, but manual supervision is required
- Class 5: High Automation-The system performs all driving tasks under specific circumstances with Geo-fencing constraints
- Class 6: Full Automation-The vehicle performs all driving tasks under all conditions with zero human interaction

Present-day systems fall in the Class 3 category inching towards Class 4. However, Class 5 systems are still under active research. They have a new set of problems to address before the system reaches full automation.

During my PhD at Indian Institute of Technology Hyderabad, I worked on aerial autonomous systems. The future of transportation will be multi-tier commuting systems working in parallel and in perfect sync. Autonomous aerial travel is still very nascent compared to ground vehicles but is a highly researched area around the world. To start with, we narrowed the problem definition to autonomously detecting and tracking targets beyond visual range without any manual intervention. The proposed problem has numerous applications in the e-commerce industry, disaster relief operations in inaccessible terrains, medical transport etc.

We designed and developed a custom UAV architecture integrated with custom hardware ob-board the UAV for autonomous object homing beyond visual range. Fig. 2 shows the proposed architecture. The proposed solution is based on deep learning. The system is designed to automatically take off and fly in known bearings (i.e. initial conditions). After clearing visual space, the algorithm on board the Jetson Nano Board enters the search phase, continuously looking for the object of interest. Once the object is detected, the algorithm is set to track mode, which continuously manoeuvres the UAV towards the object. When the UAV is in the pre-defined range of the object, the terminal mode is activated, and the UAV lands before the object of interest and delivers the package.

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The autonomous control is field tested with pre-defined control commands generated at random instants, and the UAV successfully followed the commands from the launch point and back. The work is published in Springer Journal of Real-Time Image Processing titled "UAV-based autonomous detection and tracking of beyond visual range (BVR) non-stationary targets using deep learning". A patent is applied to the architecture, which is published in the open domain. For further details, I encourage the interested reader to study the paper available in the springer library.

Conclusion:
The presented solution is part of a smart mobility ecosystem, which encompasses a wide range of alternative modes of transportation, including traditional gas and electric vehicles, bike and scooter share programs, autonomous ground and aerial vehicles, rail lines etc. The systems that handle benign conditions are already developed and field tested. However, the development of fully automated systems in complex environments is still an active area of research. To the best of our knowledge, the work presented is the first step toward autonomous aerial systems.

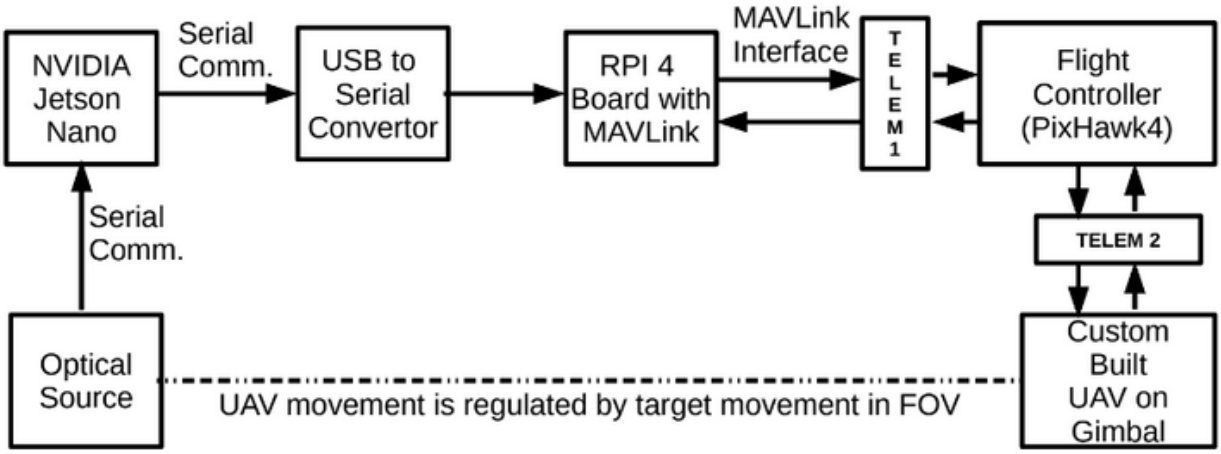

Figure 34: The proposed architecture for real time implementation

My Life @IIT Hyderabad:
Hi, I am Chandrakanth, an external PhD student in the Electrical Engg department. I am a scientist working in DRDO. I love music, reading books (currently reading Sapiens by Yual Noah Harari, it's awesome), watching movies and cooking. I hope to direct a movie. (It's a secret, so don't tell anyone)

I am a Hyderabadi. Born and bought up in this beautiful city. I did my Master's from IIT Bombay and was planning to do my PhD there. But since, since I am a working professional I had to choose a place where can commute regularly and interact with my advisor and fellow students. My Master's Thesis Supervisor suggested me to join IIT Hyderabad, which is progressing rapidly among second Tier IITs and has a wonderful campus and excellent faculty. I am glad I joined IIT Hyderabad, where I could find my mentor, who is an amazing gentleman both personally and academically. Its been a privilege to work with him, which I will cherish my entire life.

Learning new things is my passion. So, I have always been pushing my boundaries, taking new subjects and topics which helped me broaden my knowledge. So I would say all the subjects I took, I enjoyed learning them, and If I have to pick one it would be Machine Learning based Image processing.

Yes, definitely. With the knowledge I gained at IITH, I proposed the very first autonomous UAV design, which is patented.

The best Moments @IITH would be the discussion and presentations we had in our lab. For my first semester, I stayed in the hostel to finish my coursework. I had some fond memories with my roommate and neighbours.

To existing folk, I would like to say that enjoy every moment to the fullest. Take part in as many activities as you can. Find your passion. Don't just be a book bug; broaden your horizon. Make good friends and good memories, and make the best of the IITH experience.

IITH has amazing faculty. The research done is at par with first-tier IITs. The only drawback is there is no proper relationship between management and students. A common portal which everyone can access and a dedicated team to solve the problems posed by the students.

I would request IITH management to encourage, motivate and help the students as they are the future of this country.

You can always reach me at chandrav.iitb@gmail.com.

To conclude here, I would like to say that **"Never Regret. Never be afraid to try new things. These are the most precious days of your life; make memories which you will cherish forever. Time and health are the only variables that really matters in life. so don't waste time and stay healthy in mind and body."**