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Unmanned Aerial Vehicle (UAV) - Based Platform For Atmospheric Quality Monitoring and To Ensure Air Quality Standards of World Health Organization (WHO)

Air pollution has reached critical levels causing major impacts on health and economy across the globe. Air pollution poses a major threat to health and climate. The combined effects of ambient (outdoor) and household air pollution cause about 7 million premature deaths every year, largely as a result of increased mortality from stroke, heart disease, chronic obstructive pulmonary disease, lung cancer and acute respiratory infections. More than 80% of people living in urban areas that monitor air pollution are exposed to air quality levels that exceed the World Health Organization (WHO) guideline level of 10μg/m3, with low - and middle income countries suffering from the highest exposures. Outdoor air pollution is a major environmental health problem affecting everyone in low, middle, and high-income countries.

Ambient (outdoor) air pollution in both cities and rural areas was estimated to cause 4.2 million premature deaths worldwide per year in 2016 this mortality is due to exposure to small particulate matter of 2.5 microns or less in diameter (PM2.5), which cause cardiovascular and respiratory disease, and cancers. People living in low - and middle-income countries disproportionately experience the burden of outdoor air pollution with 91% (of the 4.2 million premature deaths) occurring in low - and middle income countries, and the greatest burden in the WHO South-East Asia and Western Pacific regions. The latest burden estimates reflect the very significant role air pollution plays in cardiovascular illness and death. More and more, evidence demonstrating the linkages between ambient air pollution and the cardiovascular disease risk is becoming available, including studies from highly polluted areas. Addressing all risk factors for non communicable diseases including air pollution is key to protecting public health. Most sources of outdoor air pollution are well beyond the control of individuals and demands concerted action by local, national and regional level policy makers working in sectors like transport, energy, waste management, urban planning, and agriculture.

Air quality is closely linked to earth's climate and ecosystems globally. Many of the drivers of air pollution (i.e. combustion of fossil fuels) are also sources of high CO_2 emissions. Some air pollutants such as ozone and black carbon are short-lived climate pollutants that greatly contribute to climate change and affect agricultural productivity. Policies to reduce air pollution, therefore, offer a " win - win " strategy for both climate and health, lowering the burden of disease attributable to air pollution, as well as contributing to the near - and long - term mitigation of climate change.

In 2016, Sixty - Ninth World Health Assembly of WHO identified the road map for an enhanced global response to the adverse health effects of air pollution. It this assembly "Tools developed and technical support provided to strengthen capacity for harmonization of country level monitoring, data collection and analysis on air quality and health, including in cities and in homes" were highlighted.

Environmental monitoring and control agencies, as well as industries, require a reliable, economical and easy - to - deploy tool, to assess pollution levels and on that basis, take the necessary actions.

Current measurement methods using pressurized balloons, satellite imagery, or earth stations result in considerable investment, as well as providing low space - time resolution. In Sri Lanka, ambient air quality monitoring has been carried out at Colombo Fort Air Quality Monitoring Station since 1998. However it posses limited air quality data.

This article discussed and proposes the design and development of a system for measuring atmospheric pollutants and tracking contamination sources with the use of an UAV and real-time processing. The aerial platform will allow to identify in a timely, autonomous and safe manner the sources of air pollution and the monitoring of the air quality with the advantage of providing a high space-time resolution.

Common methods used for monitoring pollutants in the atmosphere are performed by balloons with sensors, towers (or ground stations) with sensors, manned air vehicles and satellites. In order to quantify the effects on human health and the environment, detailed information on the distribution characteristics of aerosols and the concentration of pollutant gases is required. However, the spatial and temporal resolution of data collected by ground stations, balloons, manned aircraft and satellites are relatively low and not suitable for local and regional applications. Disadvantages of common platforms have promoted the use of UAVs, which promise effective, multi objective, flexible solutions, with low cost and high resolution monitoring of time and space and the advantage of being deployable in hazardous environments.

The use of quadcopters (Fig. 1) is common among researchers because they can perform tasks where high precision positioning in 3D spaces is required. It is the UAV that has the ability to take off and land vertically. The advantages of the quadcopter are manoeuvrability, compact design, and easy control. Relevant elements of the quadcopter are frame, which is the basic structure used to mount all the equipment of the aerial vehicle the direct current motors whose capacity to transform electrical power into speed is characterized in Kilo volts the flight controller, which keeps the position of the UAV stable the motors speed controller and the battery on which depends the flight time and load capacity of quadcopter.

Fig. 1 : Quadcopter for air pollution tracking

Monitoring and tracking system

Fig. 2 shows the monitoring and pollutants tracking system proposed. The quadcopter carries sensors that capture data of atmospheric pollutants and others that support UAV navigation. These data are processed in real-time through a metaheuristic algorithm and as output the system provides the navigation coordinates, which are sent to the flight controller of the quadcopter, to guide it on the search for the source of pollution. A ground control base is also available, which receives real-time data from the UAV and displays trend graphs of air pollutants. In above section and below figure mentioned the metaheuristics it means In computer science and mathematical optimization, a metaheuristic is a higher - level procedure or heuristic designed to find, generate, or select a heuristic (partial search algorithm) that may provide a sufficiently good solution to an optimization problem, especially with incomplete or imperfect information or limited computation capacity.

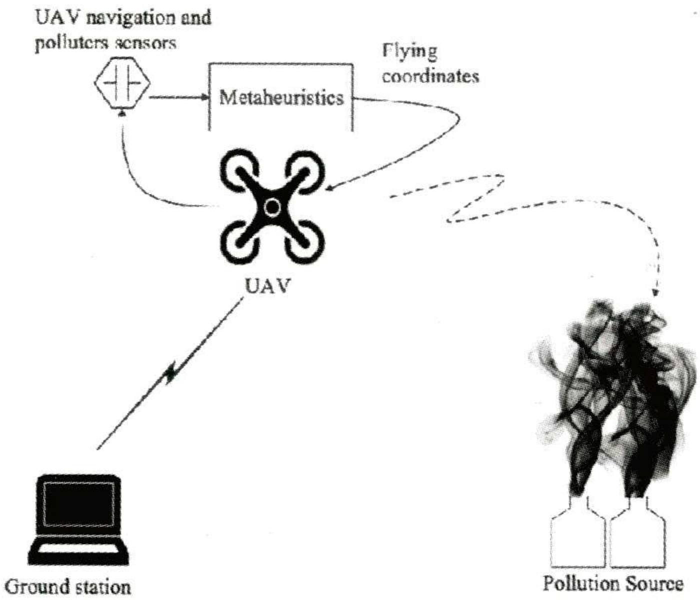

Fig. 2 : Environment of monitoring and tracking pollution system

Different types of algorithms for tracking pollutants

The scientist used different types of algorithms for launching tracking pollution systems. There is a positive and negative impacts shown in varies algorithms. The one of algorithm to control the UAV for automatically monitoring a specific area called Pollution-driven UAV Control (PdUC) based on the chemotaxis metaheuristic concept. This procedure helps for automatically monitoring a specific area we have analysed. To search an area for the highest pollution concentration levels. Once this pollution hotspot is found, the flying drone covers the whole area by following a spiral movement, starting from the most polluted location.

This algorithm is composed of two phases

(i) A search phase, in which the UAV searches for a globally maximum pollution value.

(ii) An exploration phase, where the UAV explores the surrounding area, following a spiral movement, until one of the following conditions occurs: it covers the whole area, the allowed flight time ends, or it finds another maximum value, in which case it returns to the search phase.

Chemotaxis Metaheuristic

The use of rotary-wing UAVs, equipped with chemical sensors and tasked to survey large areas, could follow chemotactic mobility patterns, since their flight behaviour could easily implement the following two-phase algorithm: first, read a pollution concentration while hovering; next, follow a chemotactic step Chemotaxis metaheuristics are based on bacteria movement. In this model, the microorganisms react to a chemical stimulus by moving towards areas with a higher concentration of some components (e.g. - food) or moving away from others (e.g. - poison).

Unmanned Aerial Systems (UAS) have been quickly adopted in different application areas due to their flexibility and relatively low cost. Most of time the scientist only considered operations limited to a single UAV. If researches can introduce multiple-UAVs and the associated cooperation schemes is most effective than this single drone method.

Capabilities of Proposed UAV

- Real-time monitoring multiple air pollutants.
- A stable high precision X-Y-Z platform for air sample collection.
- Monitoring multiple air pollutants with a modular design and lightweight sensors.
- Flight on pre-determined pathways.
- Adequate flight time for various integrated and time series data collection missions.
- Autonomous methods for sample collection.

Challenges in UAVs for air quality monitoring

- Energy efficiency and flight time

Carrying the platform will reduce the drone flight time, because the platform adds weight to the drone and the platform itself consumes electricity. There is a large power consumption space for us to study and find an optimal design with hardware and software to reduce the weight and the energy consumption of the platform.

- Synchronization of monitoring sensor data and GPS data

For real-time monitoring and geo-spatial data modelling, need to synchronize air pollution data and GPS data, because they come from the air pollution sensor and the drone separately. The internal clocks of the sensor and the drone are not synchronized at all. Rather than synchronizing the devices, we will study and develop mechanisms to produce synchronized data within an error tolerance.

- Multiple air pollutants

Air pollutants are present as mixtures in all the air environments, both the scientific community and regulatory agencies have been shifting from the traditional single-pollutant approach toward a multipollutant approach to quantify the health consequences of air pollution mixtures. Current applications mostly focus on particles, sometimes ignoring many other pollutants of concern, e.g., volatile organic compounds (VOCs).

- Planned flight path

The drone's flight path must be planned and aligned with the need to geo-spatial data profiling and modelling. It is challenging to create an optimal flight plan under a variety of constraints. Since drone's flight time is limited, we need to plan an optimal flight path so that we can collect sufficient data along the path to build geo-spatial modelling of air pollution around the area of interests. Meanwhile, we need to consider other factors in the flight plan. For example, we need to include GeoFencing into the flight plan to avoid no fly zones.

- Validity of sensors

Because of often not validated before the real monitoring, and some experiments have found significant disagreements with reference methods. Thus, the performance of miniature sensors need frequent calibrations and comparisons.

Sri Lankan context and to ensure air quality standards of (WHO)

To consider the Sri Lankan context the few industrial zones located in semi urban areas and also many people living in or near large cities, which has been identified as a leading risk factor for global disease burden. The current monitoring capacity is insufficient for reliable evaluation of public health risk, identifying emission sources, or implementing effective pollution control strategies. Because of that the level of atmospheric pollutants in industrialized zones is very important factor to healthiness of the people who living in surrounding the industrial zones. The compare with ground stations drone applications provide better picture about pollutant levels in industrial zones. The Influence of the wind is difficult to monitor in ground stations. But drone application sampling procedure includes sensors that are sensitive to the wind conditions. So it can helps to reached accurate decision in order to influence of wind nature. In addition, wind causes the overall pollution map to be more dynamic. Due to land scarcity and lack of labour these is a trend to centralized industries in large cities. Because of that warranting the need to develop reliable UAV platforms for air pollution monitoring in Sri Lanka.

Relevant authorized agencies of air quality monitoring in Sri Lanka have to focus on introduction and implementation of real time air quality monitoring UAV platforms to ensure WHO air quality standards in Sri Lanka.

References:

1. A. Seaton, D. Godden,W. MacNee, and K. Donaldson, "Particulate air pollution and acute health effects," The Lancet, vol. 345, no. 8943, pp. 176–178, 1995.
2. Aarts, E., Korst, J., and Michiels, W. (2014). Simulated annealing. In Search methodologies, 265{285. Springer.
3. Alvarado, M., Gonzalez, F., Fletcher, A., and Doshi, A. (2015). Towards the development of a low cost airborne sensing system to monitor dust particles after blasting at open-pit mine sites. Sensors, 15(8), 19667{19687.
4. Bates, T.S., Quinn, P.K., Johnson, J.E., Corless, A., Brechtel, F.J., Stalin, S.E., Meinig, C., and Burkhart, J. (2013). Measurements of atmospheric aerosol vertical distributions above svalbard, norway, using unmanned aerial systems (uas).
5. Kersnovski, T., Gonzalez, F., and Morton, K. (2017). A uav system for autonomous target detection and gas sensing.
6. Alvear, C. T. Calafate, E. Hern´andez, J.-C. Cano, and P. Manzoni, "Mobile Pollution Data Sensing Using UAVs," in Proceedings of the 13th International Conference on Advances in Mobile Computing and Multimedia, MoMM 2015, pp. 393–397, Brussels, Belgium, December 2015.
7. Alvear,W. Zamora, C. Calafate, J.-C. Cano, and P. Manzoni, "An architecture offering mobile pollution sensing with high spatial resolution," Journal of Sensors, vol. 2016, Article ID 1458147, 2016.