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UAV Delivery System

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Abstract – UAVs have become an area of interest nowadays. With this rapid growth in-home deliveries, the Ariel Delivery system with Ariel UAV deliveries can be a promising response to late deliveries, more manpower, heavy traffic jams. So, to deal with this situation, this technology of AI UAV DELIVERY SYSTEM using the latest techniques and algorithms can be introduced, which can be a low cost, intelligent, efficient, and secure alternative for deliveries of packages in urban regions.

This paper includes how this AI Delivery model can be introduced in place of our traditional delivery system. Also, this paper focuses on public review stats to analyze the costs and working of UAV Delivery systems compared to Traditional Delivery systems and how they can be useful, this paper accounts latest techniques and methods which can be implemented in this model of Ariel Delivery system.

Keywords: Smart Drones, Ariel Delivery System, AI Drones. UAV Deliveries, Drone Deliveries, Unmanned Ariel Vehicle, IOT controlled Drones.

I. INTRODUCTION

In recent decades UAVs (Unmanned Ariel Vehicles) or have gained ample popularity in recent decades in many areas, with UAVs, we can realize this concept of the Ariel Delivery system as an efficient and low-cost delivery system. According to estimated stats, it may reduce the manpower to 70% and surely which will lead to a reduction in major costs and will lower the road capacity. This model of the ariel delivery system can be much more efficient and economical as compared to the traditional delivery system which generally is using trucks, motorbikes, and other road vehicles, and it can bypass the factors like Road Jams, Construction, roads blockage which are a hindrance in the Traditional Delivery System.

Daily the interest in UAVs is increasing due to their wide use in different applications like inspection, surveillance, etc. Drone deliveries have become an area of interest nowadays, and many organizations are trying or have implemented it. Amazon introduces *prime air* service [1], which employs Multirotor UAVs to deliver packages to customers, Google X introduced *project wing* and is been running for two years [2], the main aim of the *project wing* was to develop such UAVs, that could be used in emergencies like earthquakes. The United Arab Emirates announced that the government will be using UAVs for official purposes being a secure alternative in place of the Traditional Delivery System. Zomato, India announced to use of Drones for hub-to-hub deliveries, in collaboration with TechEagle.

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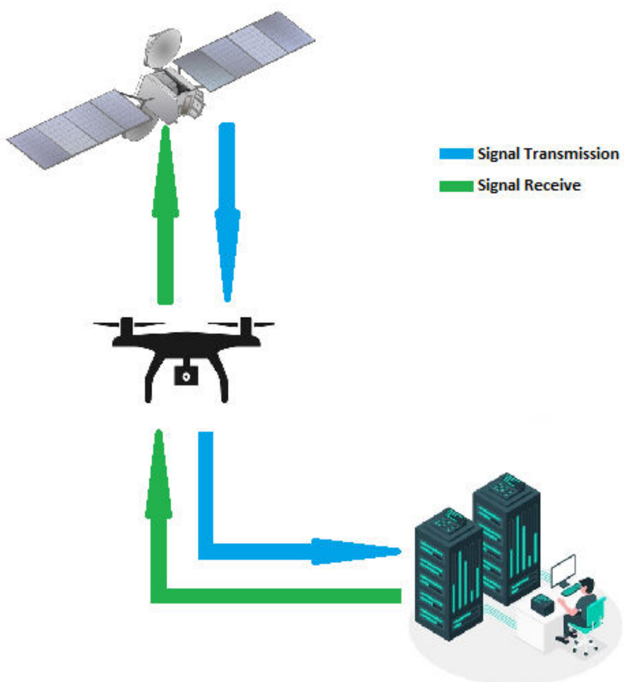
Not only deliveries but such model can be efficient in responding to emergencies for requirements like medical supplies and other needs and other scenarios where mobile ariel facility is to be employed like long time surveillance, monitoring in mobile places.

This paper represents a Quadrotor UAV Drone as the mode of delivery to the client, and the optimal number of launch-pads and charging stations in a region to facilitate this delivery system and with recent advancements, this model can be realized. In this study, UAV Drones will be expected to serve an optimal area for deliveries, also launchpads/supplying hubs and charging stations have to be set up to facilitate this delivery system.



The UAVs will follow a proper path planning algorithm, with which they can find the most optimum path between two points in space. In this study, the node and facility will be the respective points. This generally takes a bunch of values such as the position of both nodes and obstacles between the way, and algorithms follow a qualitative approach to find the optimal path avoiding obstacles with the lowest cost and time possible. In this study, the *Dijkstra Algorithm* will be taken into account to optimize the distance as much as possible and find the shortest distance between two nodes. Also, UAVs must have to ensure that the shortest path is calculated by avoiding the obstacles between both nodes [5]. This is briefly discussed in Section IV of this paper.

[10] After this path-planning algorithm, a Vehicle Routing Problem must be taken into account, it is concerned with designing the sets of routes for each UAV to ensure low-cost and fast deliveries to the customer nodes. VRP can be defined as combinatorial optimization to minimize the total distance traveled for a set of routes when the depot and the number of customers is given with known geographical locations. Every node is visited once by one vehicle from the whole fleet.

The UAV's perseverance also depends, if the distance is relatively more, it might have to visit charging stations to reach the node and then back to the facility i.e., supplying hub/launchpad. To determine the optimal number of charging hubs and their geographical locations, a distance-constrained hierarchy can be taken into context.

As in this model, UAVs will be employed, which are unmanned, so in order to ensure UAV and package safety, an autonomous model of obstacle avoidance has to be introduced in order to complete delivery safely to the delivery nodes. [13]

This paper is organized as follows:

Section 2 refers to the public review regarding the traditional delivery system and how the Ariel Delivery system can be a promising response to the limitations in the traditional delivery system.

Section 3 describes the related work done by other scientists and researchers and other literature of the same domain.

Section 4 describes the main Drone delivery problems, how they can be taken into account, and their solutions. This goes with describing a proper 3D path planning algorithm, followed by describing the energy consumption by multirotor UAVs and solutions for long-distance trips, then followed by a Vehicle Routing Problem for multiple deliveries.

Section 5 describes the Obstacle Avoidance model which can be introduced to UAVs, to ensure UAV and package safety, during the trip.

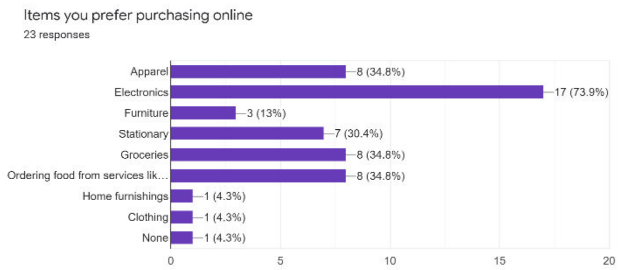
Section 6 describes the conclusions and future scope for this model of Ariel Deliveries.

Then References helped me in the successful completion of this paper.

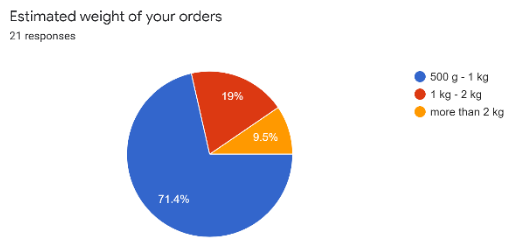
II. PUBLIC REVIEW

This would be an economical and efficient way of deliveries to nodes from the facilities as according to a public survey, 95.7% of people are ordering items and services at their doorstep,

in which maximum number of purchases are for Electronics, Apparel, Stationery, Groceries, and ordering food from services like uber eats



and such items weigh relatively low as compared to other items. According to stats, 71.4% of orders weigh less than 1 kg of weight



and according to this survey in our traditional delivery system, only 23.8% of orders get delivered within 1 or 2 days, but implementing this new Ariel Delivery system can surely, limit the delivery time and other factors like costs, and can improve security and efficiency

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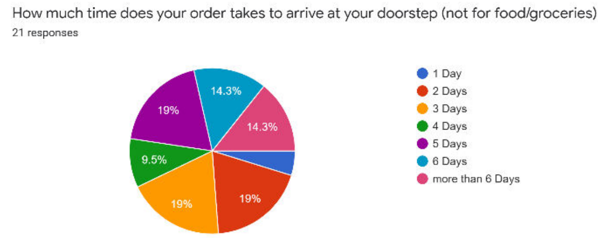
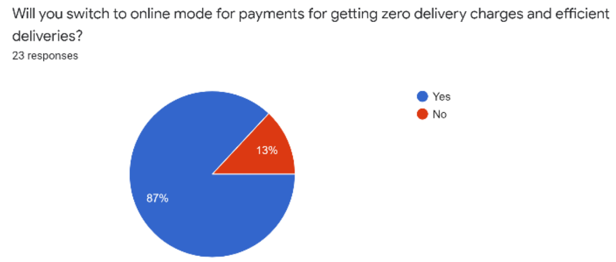


Also in our traditional delivery system, the things which the clients are afraid of are majorly Shipping expenses and wait for the item to arrive at their doorstep i.e., 52.2% and 69.6% respectively. But this won't be the case with this new model of Ariel Delivery system.

But as a matter of fact, many people are using the facility of Pay on Delivery, which can be a hindrance in opting for this New Ariel Delivery system, but 87% of people agree to pay online if the delivery expenses are less and deliveries get efficient.



With this analysis, this model can be an efficient, economical, and smart strategy over our Traditional Delivery System. This can replace manpower with smart UAVs and could save a lot of costs to clients as well as to the facilities. This new Ariel Delivery system can overtake the current Traditional system in all the aspects such as delivery time, efficiency, costs, and security.

II. LITERATURE REVIEW

Paper [3] gives an overview of the drone structure and components and a slight working of this new ariel model of deliveries. Paper [4] purely focuses on the latest and efficient Vehicle Routing Problems [VRPs] which can be employed in the UAVs in this model, it basically focuses on MTVRP (Multiple trip Vehicle Routing problems), and Green VRP. MTVRP was first described by Fleischmann in [8], but it was described for one kind of vehicle only. Paper [5] describes the A* and the Dijkstra algorithm, with proper comparisons among them and implementing them on the drone model. Paper [9] describes the helicopter aerodynamics, for a single rotor helicopter. Paper [10] focuses on MTVRP (Multiple trip vehicle routing problems) and the algorithms which are further advancements of MTVRP i.e., NENBMTVRP (Nearest neighbor MTVRP) and TSMTVRP (Tabu search MTVRP), this paper described these algorithms, in respect to the traditional delivery system, where drivers were supposed to be on job for deliveries. Paper [13] describes the building of an autonomous obstacle avoidance model for the UAV.

III. STRUCTURE AND COMPONENTS

The structure of this UAV will comprise a normal multirotor quadcopter. Using a Raspberry Pi micro-computer as the on-board processing unit, it can be used as a platform for GPS (Global Positioning System) with the advantage of DGPS (Differential Global Positioning System) to improve positional accuracy and eliminate pseudorange errors, flight control system to perform VTOL (Vertical Take-Off and Landing) [5], and will be interfaced with a camera for video streaming. The data link to this Drone will be provided through a GSM module for wireless communication with other entities like satellite and remote stations. LiDAR (Light Detection and Ranging) technology can be used to avoid obstacles or other UAVs in the air. Lithium Polymer batteries can be employed to supply enough power to take the UAV with the package to the target, or another power station, and continue the delivery. And solar energy can also be introduced with solar panels further to reduce the number of charging stations, it can be a powerful and environment-friendly source of power, and a great option as well to deliver power to UAV seamlessly.

A package locking system can be introduced for security purposes, this could be in form of mobile OTP (One-time-password) which can be used as a primary key available to both user and UAV or any other verification method for ensuring the safe and secure delivery of packages.

IV. THE DRONE DELIVERY PROBLEM

IV(A). DIJKSTRA ALGORITHM

Dijkstra algorithm is one of the renowned path planning algorithms to find the optimal distance between two

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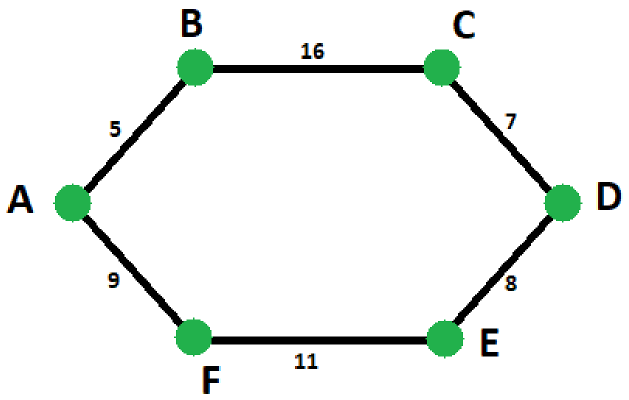
nodes avoiding the obstacles and keeping the distance as low as possible though it's also called *the Greedy Algorithm* [7].

The function used for distance calculation:

$$f(n) = g(n)$$

The approach followed by Dijkstra Algorithm [8]:

1. Create a set that keeps track of vertices whose minimum distance from the source (the facility) is calculated.
2. In the input graph, initialize the distance values as 0 and INFINITE for the source vertex and other vertices, respectively.
3. While the set created doesn't include all the distance values of all the vertices:
   a. Pick a vertex u, which is not present in the created set and has the minimum distance from the source.
   b. Include the value of u into the set.
   c. Update the distance values of all adjacent vertices of u. Then to update the distance values iterate through all the adjacent vertices. For every adjacent vertex v, if the sum of a distance value of u and weight of edge (u-v), is less than the distance value of v, update the distance value of v.



Dijkstra Algorithm is a 3D path-planning algorithm and is most commonly used in autonomous UAVs and other mobile robots. In the case of 3D algorithms, the UAV; can bypass the obstacles from the top which are less than the altitude of UAV, but in the case of 2D algorithms such as the A* algorithm which is a heuristic algorithm the UAV might have to cover a little more distance to avoid the obstacle which takes more time than Dijkstra Algorithm. To implement this Dijkstra Algorithm, the program on which UAV is running must be provided with the starting point and target point and the height of obstacles in between. To reach the target in the minimum time possible, UAVs are required to follow the shortest path avoiding all the obstacles between source and target.

IV(B). ENERGY CONSUMPTION BY MULTIROTOR UAV

In paper [6], scientists derive an equation for the power consumed by the UAV as a function of weight on board describes that the power consumed by the UAV is approximately linearly proportional to the weight on board i.e., the weight of the battery in addition to the weight of the package. So accordingly, if the weight of the package and battery is relatively more it would consume more power and if the power which the drone consumes is not sufficient to deliver the parcel and come back, in that case, the Drone has to visit one or more charging/fueling stations between the trip.

Leishman described the expression for power P^* in Watts for a single rotor helicopter in [9], the T represents Thrust in Newtons, ρ represents the fluid density of air in kg/m^3 and ς as the area of the spinning disc in m^2

$$P^* = \frac{T^{3/2}}{\sqrt{2\rho\varsigma}}$$

Section 3 of [6], describes the equation, derived for the power consumed by a multirotor drone in hover only, not during the flight, take off, or landing. It was assumed that the average power during take-off and landing, and hover is approximately equivalent. Assuming the mass of each rotor as W + m. Each carrying battery and package weight on board as

$$m' = \frac{m}{n}$$

and the skeleton weight as

$$W' = \frac{W}{n}$$

so, the power consumed by all n rotors is

$$P = nP' = (W' + m)^{3/2} \sqrt{\frac{g^3}{2\rho\varsigma n}}$$

So, with such a method, the UAV will be able to reach the target successfully with the solution to such DDP, if the battery is not capable of supplying enough power to make the drone reach the target and then back to the facilities, in such case the drone might have to visit nearest one or more charging stations to complete the delivery in optimum time.

IV(C). THE VEHICLE ROUTING PROBLEM

The Vehicle Routing Problem (VRP), can be defined as combinatorial optimization to minimize the total distance traveled for a set of routes when the depot and the number of customers are given with known geographical locations. This can be applied to this project if one UAV can perform multiple deliveries in one trip.

A single UAV may handle multiple deliveries in case of lightweight packages, and to conquer such deliveries the UAV must follow a proper VRP, as described in [10] the NENBMTVRP (Nearest neighbor multiple trip vehicle routing problems) can be implemented to optimize the distance and time, [10] is based on the traditional delivery system. So, to implement it to this Ariel delivery system, the overtime criteria can be skipped as it does not imply to this delivery system and the weight on board will be much lower. This approach can be a suitable fit for UAV Deliveries to customer nodes as this is much efficient and can cover deliveries at low cost and distance.

Nomenclature:

Layer: a set of routes,

Tour: a set of routes assigned to the UAVs,

N: total delivery nodes,

V: total number of UAVs deployed in the layer.

Q: maximum carrying capacity of a UAV

T: the maximum time when each UAV is on job

N_r: total routes in the solution,

n(r): number of costumers on route 'r',

t(r): traveling time of route 'r',

h_v: number of routes assigned to vehicle v

δ-neighborhood: a set of δ nearest neighbor nodes of a particular node

Tr_v: is defined as the remaining delivery time for any UAV "V"

$$Tr_v = T - \sum_{r=1}^{h_v} t(r)_v$$

In this approach, one vehicle is employed to each route, and in such a way that one vehicle visits each delivery node in its route. This algorithm covers two independent procedures i.e., *nearest neighbor* and *insertion*.

A layer is created applying the *Nearest Neighbor* procedure. Then *insertion* procedure is applied to the routes to insert unrouted nodes in the routes of the last layer. Creating a new layer using Nearest Neighbor and insertion is called a stage. This algorithm gives the solution by successively adding layers by stages.

The approach of this algorithm is described as:

1. UAVs are put in the list in descending order of T(r).
2. The first UAV (which is not yet employed for any route) is assigned a route in such an order that the route begins from the unrouted node which is farthest from the source point(facilities). But if no such routes are left, then the algorithm moves further to the insertion process.
3. Among the unrouted delivery nodes, in δ-neighborhood under a route, that node is inserted which is of least routing time. To ensure that the UAV doesn't enter in the route of any other UAV, the unrouted point must be admissible (if Q and T_0 are not exceeded). If no node is admissible to enter the route of a UAV, then a new route is assigned to that UAV.

For each unrouted node, the insertion cost(time) is calculated for each route where the node is admissible, and then the node with the least insertion cost is inserted, this process will be repeated until no more delivery nodes are admissible.

This VRP can be taken into account to optimize the distance and delivery cost (time), in case of multiple deliveries in one single trip.

V. OBSTACLE AVOIDANCE

For the development of the Object Avoidance model in UAVs in this Ariel Delivery system, the components which will be employed in this model are 2 LiDAR sensors, PIXHAWK flight controller, Raspberry Pi 3B+, GPS. Ultrasonic sensors can also be employed in this model for obstacle avoidance, but LiDAR is considered to be much more efficient than Ultrasonic sensors, their working is quite similar but the LiDAR sensors use Laser technology to measure distance, instead of Ultrasonic Sound waves.

Nomenclature:

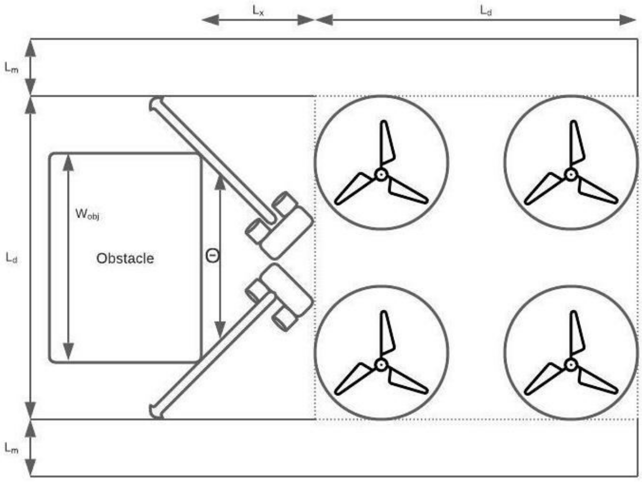
- L_s: Sensor Range
- L_m: Safety Margin, so that the propellers don't hit the object
- L_x: Distance between drone and obstacle
- L_d: Length of drone

PIXHAWK [12] will be configured with Raspberry Pi Controller to integrate the algorithm with the flight controller. The LIDAR sensors also will be integrated with the flight controller module using I2C for detecting objects between the way with the viewing angle of each LiDAR as 2°. The sensors are to be mounted at the center of the body, with the angle as Θ between each other [13]. Θ depends on the following:

- Sensor range (L_s)
- Safety margin (L_m)

To prevent the UAV from hitting the Obstacle, it is important to determine the width of the obstacle, which can be achieved with the equation:

$$W_{obj} = 2\tan\left(\frac{\theta}{2}\right)\left(L_x + \frac{L_d}{2}\right)$$



The distance between drone and object (L_x) will depend on the speed, dimensions of the drone, and the response time in which the drone will be able to successfully able to bypass the obstacle.

MAVLINK (Micro Ariel Vehicle Link) [14] Protocol will be used by Raspberry Pi to communicate with the Flight controller. The Raspberry Pi will be converting the main script written in python as the driver code for the flight controller, for which MAVProxy [15] will be used and to ease the process of this autonomous obstacle avoidance model and to give MAVProxy access to the packages of command library, Drone Kit [16] will be used which is a collection of Drone APIs in the Obstacle Avoidance Model.

VI. CONCLUSION AND FUTURE SCOPE

In this paper, I described the general public stats regarding the traditional delivery system which was currently in the role, with these stats I described the structure and the logic with which such model of Ariel Deliveries can be designed and the logic packages can be delivered from facilities to delivery nodes.

Dijkstra algorithm, a 3D path planning algorithm was introduced in the Drone Delivery model to fetch the shortest path avoiding all the obstacles between the way in the minimum time possible, this was proved as the best path planning algorithm for delivery as it was a 3D path planning algorithm as it by-passed the obstacles which were low heightened than the altitude of the drone, which saved much time than the 2D path planning algorithms. This can be linked with maps API to link determine the location of Delivery nodes, charging stations, high buildings, and other entities for the working of the algorithm.

Then the energy consumption by multirotor UAV drones was described with which if the energy supplied by the batteries were relatively insufficient, in that case with Dijkstra algorithm the nearest charging station could be determined and UAV will have to visit one or more charging stations to complete the delivery successfully.

Though this model of delivery could be efficient and secure for single trip deliveries only to make it serve for multi-trip a proper VRP was described to complete the deliveries in one route efficiently, this was achieved by NENBMTVRP, for UAVs, where no human drivers are employed.

Next, it was important for UAVs to have an AI Obstacle avoidance model to lower the risk of Package and UAV damage, to achieve that a low-cost and efficient model for obstacle avoidance was described which was based on LiDAR sensors to ensure UAV and package safety.

With more advancements, this model of Ariel Deliveries can also get more advanced in the coming years and future it could be an economical and secure alternative instead of the Traditional Delivery system.

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