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EFFECTIVE USAGE OF DRONES IN INDOOR MANUFACTURING SITES

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Abstract: The usage of drones for transportation, entertainment and media purposes was greatly increased in the last decade. Major and ambitious improvements are being made in this scientific field to reduce the weight of the units, to increase the amount of stored energy relative to the weight, to make more efficient engines, propellers and bodies to increase the flight time. This study approaches the reduction of energy usage from elsewhere: with proper planning of the drones' routes, the energy usage can be decreased. This approach can also be used in industry purposed drones, like the nowadays highlighted indoor drones, whose purpose they are to do simple logistical tasks near manufacturing areas. In this paper these drones will presented with a new energy use model.

Keywords: drones, indoor drone, route planning, AGV

1. INTRODUCTION

One of the most important tasks of any flight-capable animal is to minimise the energy consumption for the flight, provided that their capability of the flight is necessary for its survival. This is true also for the field of man-made devices. There are many ways to use energy effectively, which are predominantly technical: such as mechanical, material science, design, energy, electrotechnical and IT solutions. They are all directly trying to make the device better. With the announcement of Industry 4.0, the mode of transport is also changing, including the appearance of unmanned aerial flying transport equipment [1]-[3]. These tools are briefly detailed in Chapter 2.

However, there may also be organizational and additional fine-tunings that try to reduce the time and effort devoted to the task being carried out. For example, a route planning task that takes into account several parameters: distance, size, mass, drag, energy consumption, charging points, movement of other units, etc. Two of these, distance and energy usage are covered in Chapter 3 in the presented model.

2. TYPES OF DRONES

Drones are flying robots that include unmanned aerial vehicles (UAV) [4]. If these aircraft are automatically controlled, they can also be classified as the Automated Guided Vehicle (AGV).

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There are several divisions in the literature for grouping drones. One of them is the division presented in [5] literature, which manages size, flight distance and capabilities together:

- unmanned aerial vehicle (UAV), an example is shown in Figure 1/a [6],
- micro unmanned air vehicle (μUAV),
- micro air vehicle (MAV),
- nano air vehicle (NAV),
- pico air vehicle (PAV), an example is shown in Figure 1/b [7],
- smart dust (SD).

(a) Tilt-winged UAV [6] *(b) Pico air vehicle [7]*

Figure 1. Different examples of drones

Drones can also be divided by mass, with several groups, of which only one is detailed [8]:

- Super heavy$W > 2000\ kg$,
- Heavy $200\ kg < W \leq 2000\ kg$,
- Medium $50\ kg < W \leq 200\ kg$,
- Light $5\ kg < W \leq 50\ kg$,
- Micro $W \leq 5\ kg$.

The transportable mass may also be partially linked to the flight distance ranges.

According to the shape, several divisions are possible, the most common of which are:

- aeroplanes with wing,
- helicopters,
- flying vehicles with rotating rotors.

Unmanned aircraft and helicopters are most commonly used in modelling, which are used for hobby purposes, purely for the purpose of entertaining the operator through flying. However, on a large scale, such flying structures can already serve military or life-saving purposes.

Flying vehicles with rotating rotors, on the other hand, are increasingly suitable not only for hobby or modelling purposes, but also for other professional applications, such as military, reconnaissance, rescue, video-making, agricultural, mapping, etc. [4].

According to the number of fixed rotors without wings, the following drones are distinguished:

- monocopter (1 rotor),
- twincopter (2 rotors),
- tricopter (3 rotors),
- quadcopter (4 rotors), see Figure 2/a [9],
- pentacopter (5 rotors),
- hexacopter (6 rotors), see Figure 2/b [10],
- octocopter (8 rotors),
- decacopter (10 rotors),
- dodecacopter (6+6 rotors upside and downside).

The most common of these is the quadcopter, due to its reliability and ease of control. Most people identify the drone to this design.

(a) Quadcopter [9] *(b) Hexakopter [10]*

Figure 2. Most common designs for drones with rotating rotors

In addition to the drones of the aforementioned shape, bio-drones also occur, for example, taking the shape of an insect.

Depending on their size and use, drones are used indoors and/or outdoors.

Indoors, mainly micro-, or smaller aircraft are suitable. This is because the ceiling and walls in the interior make access more restricted, and outdoor winds make these vehicles more affected. Drones of normal or larger size, on the other hand, are more likely to be used outdoors for the reasons mentioned above.

Drones are now also used for logistical purposes [11]-[13] for which various active and passive grippers and support structures are attached, so that they can capture, transport and place small to medium-sized materials safely compared to human standards.

3. PICKING DRONES

Logistics and freight drones no longer only exist in research institutes, but are also used by several companies to carry out certain deliveries. In the United States, Amazon can send packages under 2kg to addresses within 20 kilometers of Fulfilment Centers, which can happen within half an hour of ordering [14]. There are parcel companies who are experimenting with putting one or more drones on top of their transport vehicle, which can deliver packages at a certain distance while the driver delivers another package [15].

These drones, which are already in use today, are almost without exception designed to perform a picking task. This means that a package of special size or a tray can be carried by the AGV, which is either inserted by someone (passive gripper) or taken from a predefined and constructed location itself (active gripper). The loading of the package can only be active, as these devices must work without human or special mechanical interventions.

In external spaces, especially in the case of parcel delivery, it would be unnecessary from a practical point of view to talk about a picking or distributing drone, although there are calculations [16], since the long distance and the weight limit are already very limited by the transport. If more than one package were to be delivered at the same time, it would be achieved by reducing flight time and distance, which in turn goes against the principle of distribution.

In interiors, multi-site drones already exist in production plants, especially warehouses, although the tasks there include inventory control, inventory, and surveillance. Of course, the model presented later in the article is also true for these devices, and here you do not even need to calculate with the change in weight. However, a real picking drone does not yet exist, but there are only a few uplifting reports of developments such as the A2Z distribution quadcopter [17].

3.1. Route planning features of a commie drone

As stated in the introduction, if a drone has to reach more than one location in a single journey, it becomes a route optimization problem. In practice, we rarely see a drone transporting several separate items to several different locations, with direct delivery becoming widespread. However, longer-range, and multi-purpose picking drones are already being developed and tested, which are the main focal points of this research. These drones are also capable of doing their job with as little energy as possible, as less power consumption and better design take less time to charge drones, so fewer devices can do more tasks.

3.2. It's a commie drone's route planning model

Drones move in 3D space, unlike ground vehicles, which are tested in 2D space, complete with topographical conditions. In the case of land vehicles, energy use is facilitated by the fact that there is a solid surface underneath them, which prevents the single-site position from taking up any particular energy. This is not true for flying units, as standing in one place (if possible) means overcoming gravity, using significant energy so that they do not fall. In addition, each movement that is put in different directions by the device that can fly requires a different amount of energy. The precise regulation of this is the task of electrical engineering and IT, from which it is possible to roughly determine how much energy different movements consume. This can be seen in Figure 3.

In this case, four different states can be described: levitation ($E_{Levitate}$), ascent (E_{Up}), descent (E_{Down}) and side motion (E_{Side}), which in any direction perpendicular to two side-by-side rotors (in the case of quadcopter).

If we take levitation as a basis, i.e., energy level $E_{Levitate}$ is 100%, then all other energy can be expressed by a multiplier (n_{EX}), which has already been measured by other researchers [18]:

$$\frac{E_{Up}}{E_{Levitate}} = n_{EU} \approx 1.8 \tag{1}$$

$$\frac{E_{Down}}{E_{Levitate}} = n_{ED} \approx 0{,}75 \tag{2}$$

$$\frac{E_{Side}}{E_{Levitate}} = n_{ES} \approx 1{,}15 \tag{3}$$

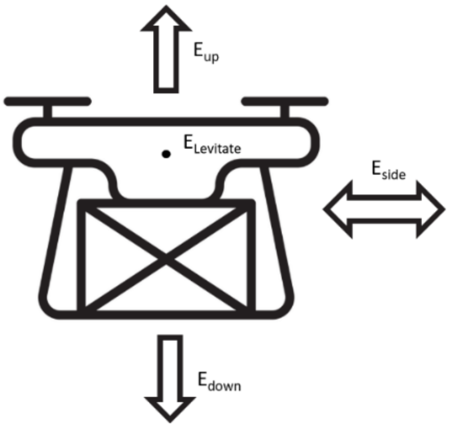

Figure3. Drone energy consumption based on directions

If possible, self-controlled drones travel between two designated points at the shortest possible distance, which is called the airline and is the easiest to calculate with the Pythagoras theorem in both 2D and 3D. In the present case, this is also the case, but at distances the energy consumption, i.e., the multiplier previously determined, must be taken into account, the corresponding directions by which an optimization algorithm calculates further as if the distances ($L_{energie}$) had increased:

$$L_{energie} = \sqrt{\left((X_n^{coord.} - X_{n-1}^{coord.}) * n_{ES}\right)^2 + \left((Y_n^{coord.} - Y_{n-1}^{coord.}) * n_{ES}\right)^2 + \left((Z_n^{coord.} - Z_{n-1}^{coord.}) * n_{EV}\right)^2} \tag{4}$$

$$n_{EV} = \begin{cases} n_{ED}, if\ (Z_n^{coord.} - Z_{n-1}^{coord.}) \geq 0 \\ n_{EU}, if\ (Z_n^{coord.} - Z_{n-1}^{coord.}) < 0 \end{cases} \tag{5}$$

3.3. A case study for route planning

The following theoretical case study shows the operation of the model prepared in the previous subsection, where a series of warehouses are taken as the basis. This reduced 3D space to a 2D space (up-and-down/left-to-left) for easier understanding and testing. In the case study, the task to be performed includes a starting point (bottom left corner; 0.0 points) and 9 points to visit on a special grid representing the warehouse and their product placement points. Warehouse size: 30 rows high and 100 columns wide, where one storage space occupies 15x15cm of space. These are the X and Z coordinates in meters, which can be seen in Table I.

Table I.

Location of commissioning items

Picking location	Column	Row	X (m)	Z (m)
1	0	0	0.0000	0.0000
2	48	11	7.1250	1.5750
3	61	16	9.0750	2.3250
4	5	22	0.6750	3.2250
5	93	8	13.8750	1.1250
6	44	25	6.5250	3.6750
7	33	18	4.8750	2.6250
8	97	2	14.4750	0.2250
9	55	28	8.1750	4.1250
10	23	6	3.3750	0.8250

Figure 4 shows the optimal route, which takes into account only the distance along the line without taking into account energy consumption. The total distance in this case is 34.9922m. The energy-efficient route shown in Figure 5 with the same calculation method is a little more than 35.2935m, which is 0.86% longer.

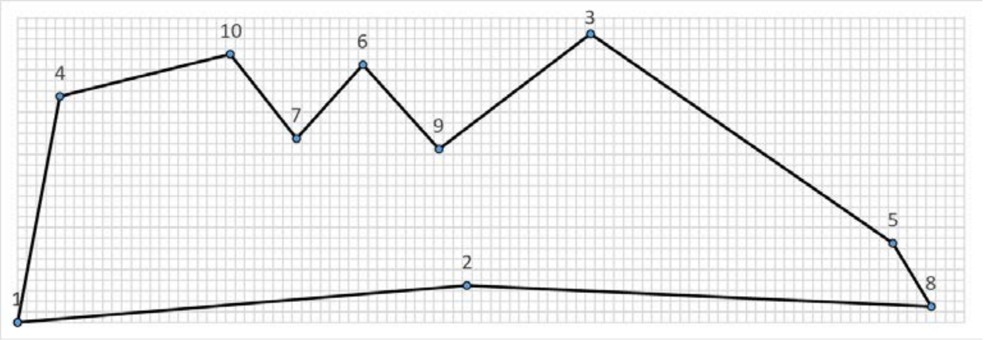

Figure 4. Result of route calculation without taking into account energy consumption

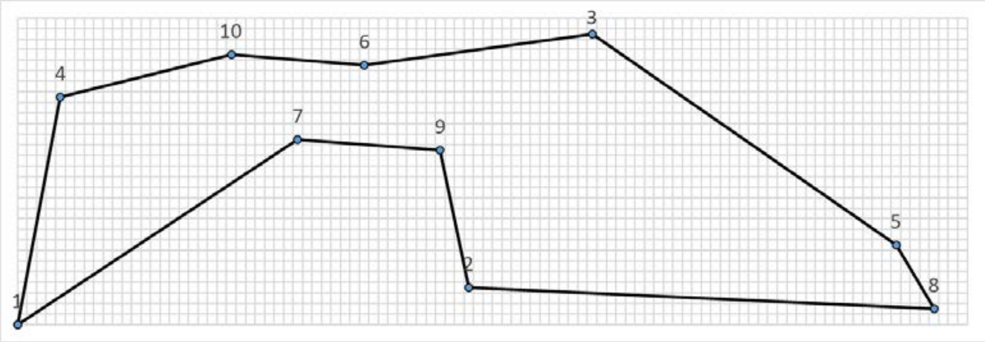

Figure 5: Result of route calculation taking into account energy consumption

If energy consumption is also measured with predetermined weights and formulae (4) and (5), the route in Figure 4 is 41.3683m(E), while the route in Figure 5 is 41.2853m(E). This gives the route in Figure 5 a 0.2% better energy consumption. Although this may not seem like much at first sight, if the discretionary energy weights (n_{EX}) increase, their effect generates an increasing difference in energy consumption.

4. SUMMARY

Nowadays, drones are becoming more and more important in our services as means of transport. Currently, most developments focus on open field applications, but indoor transport is also becoming more and more important. One result may be the picking drones, which pick up goods and distribute them in production or warehouse. Because the internal distances are not so large, a drone can reach several locations on one embankment, so route planning is required. In the work we presented a model and theoretical case study that takes into account not only distances for route calculation, but also different energy needs per direction.

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