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Study on flying car transportation system

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Abstract. With the rapid growth of population in large cities, traditional transportation modes like buses, private cars, and subways have formed a more serious traffic congestion or crowded situation. In order to solve this problem, engineers and researchers start to shift the research on the future development of transportation systems to the near-ground space (NGS). The flying car transportation system (FCTS) has become one of the major research projects. The concept of FCTS introduces a new dimension to transportation, utilizing unoccupied near-ground spaces to redefine the way both individuals and goods move within cities. FCTS, using flying cars as the main transportation means, has good development prospects. This article analyzes various aspects of FCTS in detail. The design of FCTS is introduced. The related technologies are summarized. The challenges of the future development of FCTS are also discussed. This article may offer a reference for the development of FCTS.

Keywords: Flying Car Transportation, Near-Ground Space, Urban Traffic.

1. Introduction

Throughout human history, the evolution of transportation systems has come with the development of civilizations. From early forms of ground-based transportation to subterranean transit and high-altitude aviation, human's quest for more efficient and convenient ways to connect cities, nations, and continents has been relentless. However, in recent decades, with global-scale rapid urbanization and population growth, traditional ground-based transportation systems and freight networks have found themselves under immense pressure. Urban traffic congestion and strained infrastructure have become pervasive challenges plaguing local governments and economies worldwide. In response, the field of transportation engineering and research has witnessed a resurgence of innovative solutions aimed at redefining the use of NGS for transportation purposes.

The emergence of Near Ground Transportation Systems (NGTS) represents a paradigm shift in urban mobility. NGTS explores the largely untapped potential of near-ground spaces, not only horizontally but also within the lower altitudes, providing an innovative solution to address the pressing challenges of urban congestion and infrastructure overload. Within this framework, the concept FCTS arises as a beacon of hope, harnessing the underutilized airspace to revolutionize urban mobility.

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FCTS stands at the intersection of innovation and necessity. It represents a visionary approach to urban mobility, distinguishing itself from traditional ground-based transportation systems that are confined by existing infrastructure limitations. FCTS envisions a mode of transportation that liberates itself from terrestrial constraints, offering an efficient and adaptable means of navigating the modern urban landscape. The concept of FCTS introduces a new dimension to transportation, utilizing unoccupied near-ground spaces to redefine the way, in which both individuals and goods move within cities.

In this article, the exploration of FCTS has been analyzed, including its historical roots, technological intricacies, and challenges. This article may offer a reference for the development of FCTS.

2. Flying Car Design

Since the beginning of the last century, people have continued to develop flying car technology, and some technologies have been quite mature and reliable today. The three most important technologies are power battery technology, metal material technology, and vertical take-off and landing (VTOL) technology.

The battery technologies that can power future electric mobility: The development of power battery technology is inseparable from the improvement of lithium chemistry. The increasing understanding of lithium bonds will allow for safer and more efficient power battery technology, and FCTS will also benefit from it [1].

Finite element analysis of car frame frontal crash using lightweight materials: FCTS requires lighter materials than ordinary cars, but the safety and robustness of lighter materials are often worrying [2]. However, in recent years, the rapid development of material technology, especially the car companies continue to develop new alloys, plastics, and high-strength steel, and through physical model tests instead of actual collision to reduce costs. However, the material required for a flying car is far stronger than that for a normal car, so carbon fiber is more suitable for FCTS.

VTOL unmaned air vehicle (UAV) digital twin for take-off, hovering, and landing in different wind conditions: The VTOL mode combines an airplane with a car and does not require any runways [3]. Being able to take off anywhere greatly improves the efficiency of flying cars. Today, the VTOL mode has been widely used in industry. Although VTOL has been widely used, there are few cases and experiences of using it on objects such as large vehicles. For flying cars, VTOL is still a development effort.

There are still many problems with flying cars, and the most obvious and important two problems are the structural redesign of flying cars and the stability of the VTOL system.

As flying cars fly higher than the low surface, the risk of falling should be expected when the danger occurs. Therefore, unlike the frontal crash test considered by ordinary cars, flying cars require additional design and consideration of the impact and damage caused by free fall. Various situations may occur in the event of an accident, and even continuous rolling, so not only the chassis but other parts should also be tested for collision resistance.

Although the VTOL system has been used on a large scale, it is used on small and light vehicles such as drones, and there is no experience and case of large-scale use in flying cars. The VTOL model may be tested differently at different wind speeds, especially for manned vehicles. Even under certain weather conditions, takeoff may fail directly. Flying cars cannot copy the experience of VTOL on drones, and plug-ins should be used to simulate different wind speeds, different loads, and unequal-weight environments for testing. If necessary, actual take-off and landing tests should even be taken.

These two problems can be improved with some technically feasible solutions. High-altitude accidents may fall in various states, so the chassis and roof should be different from the ordinary car design. Air resistance should be considered in addition to more crash-resistant structures. For example, the chassis and roof are streamlined after takeoff, and the interior uses a strong carbon fiber triangle structure to cope with possible impacts. The approximate material of the car body cannot be like the ordinary car, should give up cheap aluminum alloy, and choose carbon fiber to further ensure safety.

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In addition to practical testing, the application of the VTOL system on large vehicles should also pay more attention to whether the weight layout inside the car is balanced, to prevent flips caused by unbalanced weight distribution.

3. Related Technologies of FCTS

Although flying vehicles are primarily intended to reduce travel times and ease traffic congestion. Severe air collisions and chaos might be caused by the high speeds operated by flying vehicles. Therefore, planning for path and trajectory is essential [4].

Accurate location and navigation are crucial during flight for a flying automobile. Hence, obtaining accurate location and navigational information is necessary. There are a few things that need to be considered for the trajectory.

3.1. Technologies for obtaining positional information

Global positioning system (GPS) is widely used to obtain two-dimensional positions. Another widely used navigating application is the cellular network, known as Wi-Fi. It is a wireless network protocol commonly used for local area networking.

3.2. Purpose of path planning

The goal of path/trajectory planning for FCTS is to create 3D geometric pathways that travel through preset points, either in government-designated restricted places or in animal protection zones, from an initial to a destination point. To meet the requirements in the application scenarios for flying cars, the algorithms for path planning are typically categorized according to the functions that are optimized in terms of transportation time, energy consumption, and jerk. Furthermore, the passengers' feelings, which may also be impacted by weather conditions along the path/trajectory, must be considered while constructing the path/trajectory for FCTS for the conventional ground public transit system.

4. Challenges of FCTS

In recent years, although flying car technology has made great breakthroughs and developments, it is still far from FCTS fully entering the commercial field [5-7]. At the same time, with the continuous innovation of FCTS technology, more non-technical problems are constantly emerging.

4.1. Safety Issues

As an innovative transportation system, safety is bound to be the most important issue. Passenger protection, stability in different weather, collision avoidance, and noise are the main problems.

Passenger Protection: In the FCTS, the trajectory of flying cars is usually tens of meters above the ground, which obviously has a greater potential threat than ordinary cars. As flying cars tend to fly rather than drive, the safety issues of flying cars are somewhat more like airplane crashes. According to relevant statistics, most air disasters occur in the two phases of take-off and descent [8]. Excluding accidents caused by human factors, temporary failure of machinery is the most common cause of accidents [9]. Therefore, to protect the safety of passengers, the establishment of a breakdown emergency mechanism system for take-off and descent is undoubtedly a very effective means.

Stability in Different Weather: The requirements for the stability of flying cars in the face of various extreme weather are very high. Establishing a high-precision weather forecasting system in the FCTS is necessary to avoid extreme weather in the flight as much as possible. In addition, the flying car itself also needs to have good stability, including the choice of its materials, the design of the structure, and many other aspects.

Collision Avoidance: There are numerous flying objects in the air, especially over cities. At the same time, if FCTS is implemented on a large scale, many flying cars will make the air more crowded within 100 meters of the ground. Currently, flying cars need to avoid collisions with various flying objects and each other. For this purpose, each flying car needs to be equipped with a high-precision obstacle

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detection system; At the same time, the ground corresponding to the flying car's driving range should also be covered with a complete ground monitoring network, to avoid such incidents as much as possible.

Noise Treatment: Just like many other vehicles, flying cars inevitably cause noise pollution. Moreover, unlike ordinary cars, flying cars need to install more powerful engines to maintain flight, which will also cause more serious noise pollution. Therefore, it is necessary to reduce the noise pollution of flying cars as much as possible. For this, flying cars can be equipped with specially modified low-noise propellers and engines, and sound-absorbing materials when manufacturing.

4.2. Commercial Issues

To judge whether a new technology is truly successful, it is necessary to measure whether it can be commercialized on a large scale. It is still too early for large-scale commercial application of FCTS, and there are still many business problems that need to be solved. Therefore, when discussing the challenges of the future development of FCTS, commercial issues are inevitable.

Manufacturing Cost: Manufacturing costs are clearly one of the most important, including the cost of manufacturing flying cars, as well as the manufacturing costs of other facilities for the FCTS. Among them, the manufacturing cost of flying cars undoubtedly accounts for the vast majority. To achieve mass production, at least hundreds of flying cars need to be built, and the capital cost will be astronomical. To this end, it is necessary to use the most advanced modern manufacturing technology as much as possible, including the selection of cost-effective new materials, and the most efficient engine assembly, to greatly reduce the manufacturing cost of flying cars.

Commercial License Application: Commercial licenses are necessary for commercialization, so the acquisition of commercial licenses is also an important commercial issue. For FCTS, the processing of commercial licenses needs to be jointly issued by the economic authorities of the local government and the civil aviation regulatory authorities. In the process, to ensure the reliability of FCTS technology, many related tests, product operations, and safety verification are required [10].

4.3. Ethical Issues

As an unprecedented new transportation system, the emergence of FCTS will inevitably challenge the underlying inherent value rules. Under such circumstances, ethical issues will also be a major challenge for FCTS in the future.

Disturbing the Ecosystem: The emergence of the FCTS has greatly increased the traffic flow within 100 meters above the ground, which will have a very large negative impact on birds living in the city all year round. At the same time, as mentioned earlier, the noise from flying cars can also disturb the animals in the city. To this end, sensitive areas with a high concentration of animals can be investigated and marked in advance, and reasonable routes can be designed to avoid them when building the FCTS. At the same time, during the driving of the flying car, the situation in the densely populated area of animals is monitored in real-time, to effectively avoid the animals that appear.

Environmental Pollution: The environmental pollution of flying cars is also one of the important ethical issues. The emergence of the FCTS provides a completely new mode of transportation, which will inevitably lead to a large increase in transportation. The exhaust emissions of flying cars will cause great pollution to the environment, and at the same time, gases such as carbon dioxide contained in the exhaust gas will also aggravate the earth's greenhouse effect and affect global warming. The use of electricity and clean energy needs to be vigorously promoted. The energy source of the flying car can be designed as a hybrid, solar energy, electricity, and other clean energy sources.

5. Conclusion

This paper has conducted a detailed analysis of FCTS in the following aspects: FCTS design, current developments, and challenges. The actual commercialization of FCTS will not be expected within at least a decade. Hence, based on the discussion and analysis presented in the paper, some guidelines for the design and commercialization of FCTS are presented:

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Safety measures and emergency mechanisms like airplanes must be devised and installed. A high-precision weather forecasting system should be established, and flying cars should be able to fully function in all weather conditions. A special system for collision avoidance must be devised if FCTS is implemented on a large scale. Trajectory planning should be employed beforehand with consideration to other flying cars and weather conditions. Autonomous piloting is currently the optimum choice for flying cars given its special characteristics. Manufacturing costs must be cut down through advanced manufacturing technology to compete with traditional means of transport. Environmentally friendly manufacturing and operation should be employed to reduce the pollution as much as possible.

Authors Contribution

All the authors contributed equally and their names were listed in alphabetical order.

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