Pizzair - A Pizza Delivery Drone

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Abstract—In response to the persistent challenges of pizza delivery, we present an innovative solution to overcome these obstacles and redefine pizza delivery. The current reliance on human drivers results in delays and cold pizzas for customers. Our solution, "Pizzair," is an AI-enabled, fully autonomous pizza delivery drone. This drone ensures fast, cost-effective, and hot pizza delivery within a 10-minute radius of a pizza restaurant. The drone is equipped with a specialized harness to securely deliver the pizza while maintaining its temperature. Pizzair's autonomous navigation system, enabled by cutting-edge machine learning techniques, ensures timely and safe delivery, even during peak demand or difficult conditions. Pizzair is intended to transform the pizza delivery industry, drastically improving customer experiences and optimizing delivery operations.

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1 Need for this project

As the popularity of the food delivery sector has grown, partially driven by the COVID-19 pandemic forcing many people to stay at home for long periods during quarantine, traditional delivery services have faced previously unforeseen stressors. Risks to drivers from disease, difficulties in maintaining customer satisfaction, ensuring consistent product quality during peak delivery hours, and decreasing standards as a result of increased demand are some of the major challenges in modern food delivery.

One solution to ameliorate many of these problems is leveraging increasingly powerful autonomous systems to help offload delivery work onto drones. Drones are fast, increasingly reliable, and after the onset cost of purchasing a drone, cheaper both economically and in terms of spent resources (human hours, carbon footprint, etc.) than a traditional delivery human in an automobile.

However, the current state of autonomous delivery systems exhibits certain limitations. Existing solutions are typically numerous, difficult to use, and relatively expensive. They have been primarily designed for long-range delivery—catering to larger payload—-such as medical supplies to remote regions. Our project is investigating the viability of a lower-cost alternative, primarily designed for urban and suburban low-range delivery, that would be a viable option for restaurants to individually purchase and use as an alternative delivery mechanism in addition to or in lieu of human delivery. In doing so, we intend to not only streamline food delivery but also contribute to a more efficient sustainable future for the delivery industry.

2 Problem Statement and Deliverables

2.1 Problem Statement

Our proposed solution will significantly decrease the waiting time for pizza delivery by offering AI-enabled drones with a low cost, high frequency delivery model. Our design will be a drone maintained by pizzerias for delivery on demand whereby customers receive hot pizzas in a defined radius within 10 minutes of it being prepared.

Users will order pizzas from restaurants on the Pizzair phone application, which alerts restaurants to prepare food and attach it to the delivery drone. During the delivery process our drone will use a combination of GPS and external sensors to power its machine learning enabled navigational techniques to reach customers' homes and carefully drop the boxes at their doors. The drone will then return to the pizza restaurant for recharging and redelivery.

2.2 Deliverables

A preliminary proof of concept indicates capability of the following:

1. Operating successfully in a controlled test environment, such as an empty field or small neighborhood block
2. Smaller delivery load capability of a couple hundred grams

A working delivery drone final prototype indicates capability of the following:

1. Maintaining temperature of food product to delivery

2. Harness mechanism allowing easy access of pizza
3. Keeping pizza unharmed under bad weather conditions
4. Costing under $3000 per drone
5. Compliance with Federal Aviation Administration (FAA) regulations

Navigation and associated codebase indicates capability of the following:

1. Self-navigation
2. Sending notifications to customer and pizzeria regarding delivery
3. Prioritizing delivery routes if multiple orders are to be delivered in short span of time

3 Visualization

Below are diagrams representing the basic system architecture and hardware structure.

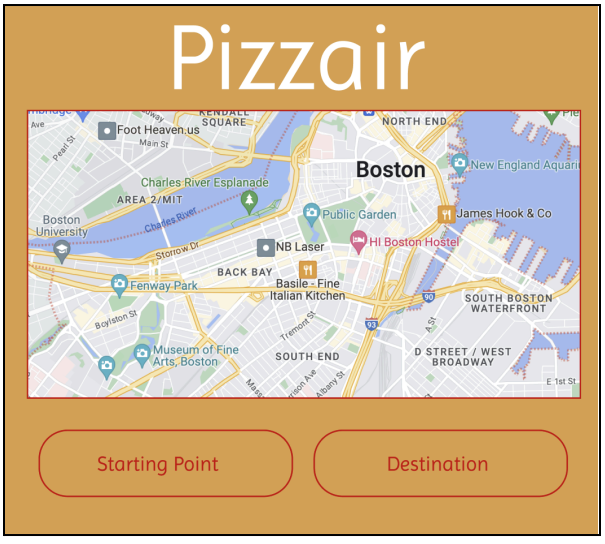

Figure 1: UI Wireframe
This wireframe represents the user interface for an app that facilitates communication with the drone. Users can input both the initial pickup location for the pizza and the final delivery destination for the drone.

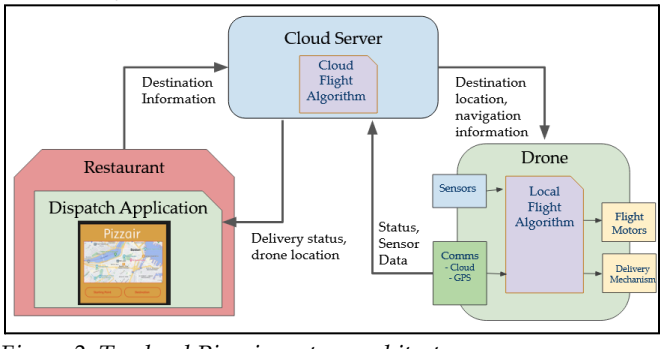

Figure 2: Top-level Pizzair system architecture.
Left: The restaurant or other client, which has access to an application where the user specifies a delivery location, receives information about the drone in-transit. Top: The cloud application layer handles communication between the restaurant application and drone. It can also handle any distributed control computation from the drone, if required. Right: The drone has an onboard computer and suite of sensors to handle navigation and control, including flight and the delivery mechanism. The drone communicates with the cloud server to handle control and status updates.

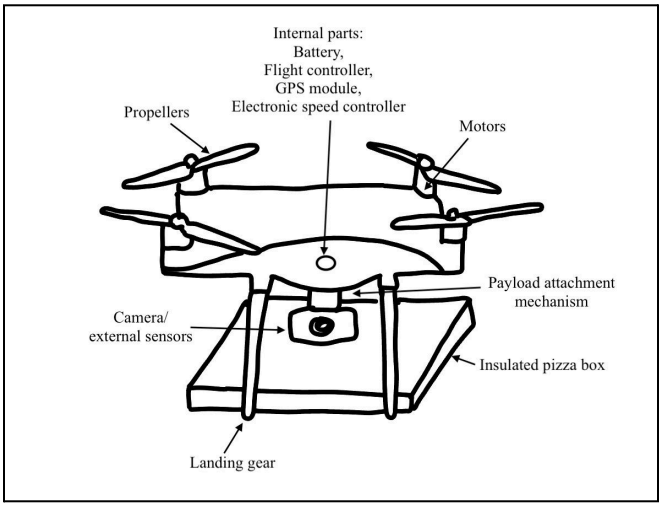

Figure 3: Hardware structure diagram.
In addition to the standard drone configurations like propellers, motors, and landing gears, the payload attachment mechanism is customized to support the safety and easy access of the pizza box below. Other external sensors are implemented to collect extra data for AI navigation.

4 Competing Technologies

4.1 Competing Solutions

The leading companies in the drone delivery industry are Amazon, Zipline and Wing. They focus on delivering a variety of packages, so most of the research in this field consists of package delivery drones in the United States. The delivery drone industry has been expanding rapidly since 2019. We are looking at existing products for inspiration for our solution and when evaluating how to differentiate our product from theirs.

4.2 Resource Allocation

One insight we have found is that drone development involves a great amount of trial and error, which will demand we utilize our time and resources judiciously. President of Ondas Holdings, a company that is partnered with Amazon PrimeAir states that “when you build a new robotic aircraft, it is going to fail early on, and you just have to work through that until it stops failing.” This realization gives us a good insight about how we should be patient in our own trials.

4.3 Legal Requirements

The current drone industry also offers important lessons on how to navigate the complicated regulations surrounding drone usage in the United States. In order to operate commercially in the United States every company has to get clearance from the Federal

Aviation Administration (FAA). One of the most important regulations is that in order for a drone to operate beyond visual line of sight (BVLOS) it has to have detect and avoid systems, dedicated modules that help drones avoid obstacles. The CEO of Wing Adam Woodwarth, in an interview with CNBC, states that they invested almost all of their resources into determining the BVLOS because truly autonomous drones cannot function effectively without it. In order to get FAA clearance, we will also implement our own detect and avoid systems. These solutions will likely require complex engineering; Zipline reports that it took them 7 years to fully engineer a system that could fly under any weather conditions, even in thunderstorms. Some companies also take into account the privacy of the customers, or opt for quiet propellers to prevent noise pollution.. These are also considerations we will consider later in our development.

5 Engineering Requirements

The requirements specified for the implementation of Pizzair include the following:

1. Delivers pizzas to within 10 minutes of starting location
2. $3000 landed cost per drone
3. Operates without safety errors in 95% of deliveries in control environments
4. Operates at 90% of ordinary efficiency in suboptimal environments (light rain or snow, etc.)
5. Ensures pizza is maintained to within 50% of ideal temperature in transit
6. Delivers pizzas directly to door using one-shot image recognition
7. Uses a machine learning-enabled imitation learning approach for obstacle avoidance
8. Compliant with FAA regulations
9. Uses removable battery for hot-swapping recharges

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References

[1] "Why Walmart And Alphabet Are Beating Amazon In Drone Delivery,"YouTube,[Online].Available: https://www.youtube.com/watch?v=yMqbj4Kj-z0

[2] "Why Amazon, UPS and even Domino's is investing in drone delivery services,"Insider Intelligence,[Online].Available: https://www.insiderintelligence.com/insights/drone-delivery-services/

[3] "Domino's is launching a pizza delivery robot car," CNN, [Online].Available: https://www.cnn.com/2021/04/12/tech/dominos-pizza-delivery-robot/index.html