PILOT: Piloting the last 100 yards

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Abstract

In the field of mobility, the focus in the past few years has been on the proverbial last mile connectivity. However this paper, narrows the scope from "miles" to the "last 100 yards" presenting a unique sets of issues that are not seen at other levels. The last 100 yards encompass routing and connectivity issues within confined spaces such as houses, apartment building, office spaces and many others. Some of the challenges in this context include coordinating between traditional delivery services (e.g., Fedex, DHL or Amazon Prime) and specialized pilots authorized to operate within the human dominated spaces of the last 100 yards. Ensuring timely delivery of perishable items, addressing the risks of delivery theft and recipient accuracy, and managing the storage and redelivery of packages when recipient are not present further complicates the process. Despite the challenges, the last 100 yards also present opportunities for novel solutions based on automation, robotic routing, social modelling, and industrial planning. In these confined spaces fully automated robotic solutions become feasible as navigation speed and routes are limited and the area can be easily geofenced.

CCS Concepts

• **Applied computing** → **Transportation**; • **Computing methodologies** → *Robotic planning*; Search methodologies; Modeling and simulation; • **Human-centered computing** → Human computer interaction (HCI).

Keywords

Navigation, Robotics, Planning, Last mile delivery, Last 100 yards, Delivery coordination, Mobility as a service, Robotic delivery, Logistics

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1 Introduction

The phrase "the last mile" was originally coined to describe the issues facing service providers such as telecommunication and utility companies from delivering their services into the residences and businesses of their customers. The term "mile" denotes the scope of the distances and the area of the region involved where "mile" connotes a small distance relative to the total distance traveled by the delivered service. The term "last" is interpreted either spatially or temporally and thus indicates that we are talking about either the area in close proximity to the point of service which can be either at the start or end of the service period.

It should be clear that these definitions are not cast in stone as sometimes the service is a sequential process which has a start and an end location, both of which are of interest Coupled with small distance values, we call our problem the "last 100 yards" problem. In the rest of the paper, we describe our vision in terms of a number of existing delivery platforms for entities corresponding to people, ready-to-eat meals, and groceries that are plagued with such problems, and show how to resolve them through the introduction of the concept of a "pilot" in the nautical sense by expanding the scope of the specialized tasks which will be performed by the pilots thereby growing the size/pool of service providers and hence the role of the shared economy in the total economy.

We consider three delivery categories: people, ready-to-eat meals, and groceries as they have been commercialized. Groceries are often delivered using carts which may be owned by the delivery system provider, the recipient of the delivery, or by the site where the delivery is taking place.

The categories do not include individually distinct perishable food items such as dairy products, fruits and vegetables as they are not the focus of any of the popular delivery platforms other than ready-to-eat meals. We also omit "big box" stores" whose delivery platforms are well-tuned to the requirements of their customers (e.g., USPS, UPS, Amazon Prime, DHL, and FedEx, to name a few). Note that supermarket deliveries from entities such as InstaCart and Giant Food's Pea Pod are permitted in the "groceries" category. Also, restaurants having "take-out" and delivery capabilities with their own drivers are included.

(1) People: Add pilots to the Uber and Lyft ride hailing/ride sharing apps to assist passengers to find their drivers. This is especially useful in the rain and on dark nights especially at airports.
(2) Ready-to-eat Meal: Add a pilot who serves in the dual role of escort and guide when making a delivery of a ready-to-eat meal especially at large apartment complexes where finding a given apartment may be a challenge not unlikely to result in the food getting cold or possibly even spoiling by the time that the apartment has been located.
(3) Groceries: Add a pilot who serves in the dual role of escort and guide as in the above ready-to-eat meal scenario, Note that the pilot would also need to locate an empty cart if he

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does not own one as well as pull/push it as necessary to the destinations as well as load and unload it.

In the rest of this paper, we describe our pilot-based solutions for the last 100 yards problem for three common mobility as a service tasks described briefly in the start of this section. They are expanded upon in Section 2. Pilot-based solutions are proposed in Section 3 while conclusions and directions for future research are presented in Section 6. Section 4 discussed the robotic pilot and so is current

2 Mobility as a Service

Uber and Lyft offer services similar to those provided by taxis with the additional feature of enabling a ride to be shared by several customers both in part as well as permitting one passenger's ride to completely subsume another passenger's ride. The modus of operation enables one rider to activate his relevant ride sharing app with a destination address which can be specified by name (and then matched to coordinates for the driver) or by direct manipulation using a map query interface where it is assumed that the passenger is departing from his current location [7, 8, 11–13]. Once the route has been chosen, the passenger is informed of the vehicle description (color, model, year) as well as the driver's name and phone number, and an estimated time of arrival for both passenger pickup and arrival. At this point, all that is left is for the passenger to meet up with the driver which it turns out is easier said than done. This is the aspect of the last 100 yards problem that we will address in Section 3.

UberEats and DoorDash are usually secure as their food delivery persons are usually not permitted to roam unescorted through the destination facility. Thus the customer needs to fetch the ordered food from the facility's front door (i.e., the lobby) possibly having to get dressed during which time the food would most likely get cold or possibly be stolen if the food delivery person is not required to acknowledge the delivery with, for example, a credit card receipt. This leads to the delivery person usually waiting for the customer and hand-delivering their meal. An alternative solution is to install lockers at the customer facility and to email the customer a delivery notice. Such lockers are frequently used for non-perishable items as they can be located quite far from the customer's facility (e.g., within 15 minute driving distance for Amazon Prime) which is usually considerably more than 100 yards which is the length of a football field. The down side of the locker solution is the possibility that the customer neglects to pick up the package. Locker providers such as "Parcel Pending" address this issue by imposing high redemption fees [14] for packages that are left for too long.

With respect to grocery deliveries by companies such as Instacart, there is no consistency with most deliveries made using bags. One of the problems with carts is that they are generally large and heavy even though they are foldable and/or collapsible.

3 Types of Pilot

The apartment complex represents a fairly closed and constrained environment where the layout of the apartments and obstacles is fairly stable. After all, it is not everyday that the layout of a building changes. Hence, in this domain there is an immense opportunity for autonomous behavior and robotics. In the simplest scenario, the pilot is a human (i.e., concierge) that accepts delivery of a package and then ensures that the same package is handed over to the tenants. In this model, the complexity is in coordinating between traditional delivery and the human pilot. For instance, the human pilot may not be present at all hours of the day so the delivery has to sync with the human pilot in order to ensure that the last 100 yards handoffs are performed seamlessly. Note that the human pilot can be a bottleneck that cannot be easily scaled up. A human pilot that is delivering a package for one tenant may not be available to take food delivery for another so this creates further short-lived coordination challenges. Due to their nature, apartment complexes can be quite challenging to navigate and therefore setting standards [6] for robot friendly environments will be imperative in the future. By simply advocating for better standardization many complex and difficult to solve problems in robotics as they are applied to building navigation could be fully avoided. Another way to alleviate the costs is by encouraging consumers to bulk their orders together which in a sense allows these containers to be self-contained pilots of differing goods headed to a common unit. The pilots in this case can be evaluated based on timely arrival and quality of good neither of which has a bound. Such systems are currently implemented by Amazon Prime through their Prime Day shipping technique [5] which encourages users to have all their packages delivered on the same day. Also in a similar manner Temu encourages bulk orders through their low prices but comparatively high limit before free-shipping applies on an order. These systems allow users to self sort their purchases into high and low priority categories rather than forcing the fulfiller to treat all orders as the same ultimately creating a more efficient solution for both sides. To ensure that each individual package can be tracked they can be installed with RFIDs inside [2, 15] which can be scanned to identify which product is contained in each parcel. This will ensure that no bulk order is every sent out while missing a part of the consumers total order.

At the airport, human pilots serve to speed up the matching of drivers to passengers and keep track of such data and use it to determine pilot compensation like $1 per successful match. Use of pilots can result in greater throughput thereby enabling more passengers to find rides. Pilots are employed by the owner of the ride sharing app or venue. Anybody can serve as a pilot in the sense that pre-requisites are similar to those for driving (vision and mobility). The pilot's work can be aided by a dedicated app which can assist in managing the team and efficiently assigning pilots to driver-passenger pairs. All pilots would be required to pass a test that asks them to identify models and makes of cars from their photos and vice versa. Pilots both humans and robots will be able to leverage an intimate knowledge of the location as well as a memory of where certain vehicles are. However the modeling of pilots here represents a unique challenge as the heuristics involved are not just spatial (such as distance to vehicle or passenger) but will also require taking into account more abstract concepts such as penalties for similar cars being mistaken for the other and other biological caveats.

Next up the technological scale are mechanical carts that do not have any sophistication. The package or food is delivered at a safe spot and the tenants have to perform the 100 yards delivery themselves. In this case, there is the age-old problem of tenants not returning these carts to their original positions so that they are available for others. Note, that there is also a capacity planning problem here. For instance, the cart demand may be very high when a delivery truck arrives but at other times there may not be any takers for these carts. Yet, one cannot provision for the peak demand since that would be too many carts lying around and occupying space.

Higher up the technology curve are fully automated delivery carts. These carts are capable of accepting delivery for a tenant, determining if the tenant is available to take delivery, automatically navigating to the tenant's address and finally making the delivery. Note that such carts would be able to accept packages for multiple tenants and be able to make all the deliveries before returning back to their starting point. The technology needed to realize such vehicles have been around for a while now and such vehicles can be built with readily available components. Still, some gaps remain which are explained in a later section.

4 Robotics Pilots at the Apartment Complex

Robotics carts that make the delivery need to have certain capabilities that can make them effective at their jobs. Since accepting and delivering packages involves interactions with the courier or driver on the ingress side and the tenant at the other, the carts have to be fairly sophisticated to make the deliveries as efficient as possible. Note that all human interactions are video recorded so that they can be reviewed later. This serves as a check for humans that may intentionally try to confuse the robotics carts and as a safety mechanism for humans dealing with a large machine with moving parts.

GeoFencing. A robotic cart is never able to leave the boundary of the apartment complex. There is a geofence that prevents the robotic cart from leaving the premises.

Driver Interaction. When the driver makes the delivery, a fleet of carts has to be ready for loading as the driver fetches more packages from the truck. Note that these carts may not have any arms to load the packages so there should be a sufficient number of them available. Note that packages that were not loaded on these carts would have to be delivered by a human later defeating the purpose of automation. As the driver loads the packages on the carts, there should be an OCR at the cart that would read the name on a package and the tenant address where the delivery needs to be made. If a package is being delivered at the wrong address or if there is no registered tenant by the name mentioned in the package, the cart would refuse to accept the package. In this case the driver has to double check if the package was sent to the wrong address. Note that the driver may override the robotic cart and force it to accept and deliver the package. All these complex interactions require suitable and consistent user interface design. Further, if a tenant has been out for an extended period, the robotic cart will similarly refuse to accept the package and would force the driver to leave the package in a safe box for the tenant to pick it up later.

Sequencing Deliveries. Once the cart is loaded the next challenge is figuring out when to deliver the packages. For packages that are perishable, the cart has to make those deliveries as soon as possible. In any case, once the package is loaded onto the cart it cannot be unloaded by anyone other than the tenant. The robotic cart may send an alert to the tenant's phone and wait for confirmation before proceeding. The robotic cart may also keep track of who enters and leaves the apartment complex but these have serious privacy concerns and hence not preferable.

Routing. Next comes the challenge of navigation inside the apartment complex. Given that we already live in the world of self-driving cars on roads, this problem seems quite tractable. The challenge here is that we do not want to build expensive machines but want to construct the carts from off the shelf components. The low speed and the constrained nature of the apartment complex means that a simpler technology may be sufficient. The cart follows a fixed route which is pre-programmed. In some sense, the robotic carts knows how to go to any apartment and how to return back to its default position. Given the slow speeds, it may not even need any sort of intricate collision prevention system. At this point, the robotic cart would simply alert a human concierge for assistance.

Elevators. Elevators are a particular challenge for the robotic carts since they do not have arms. To that end, the robotic carts would have to have wireless control of the elevators. Next, the robotic carts would have to share the elevator with human passengers (or possibly other robotic carts). This is another instance where the robotic cart should neither be too conservative in terms of never boarding an elevator with other humans nor too aggressive in terms of ramming into an already crowded elevator. Such systems have already been tested [9] where robots have been able to navigate from outside onto an elevator and up to the proper floors.

Charging. The robotic carts should self charge at the time of no activity and should ensure that it has maximum charge during the periods where it is expected to make deliveries. Since the robotic cart is expected to tow heavy packages as well and it is difficult to predict such things in advance, so it is imperative that it maintains a healthy charge.

Tenant Interaction. Dealing with the tenant is also a challenging problem for a number of reasons. The tenant may take packages that may not belong to him. In that sense, the robotic cart has to verify and sound appropriate escalations if the tenant is being dishonest. A tenant may also not take delivery of their package and at that point the robotic cart will need to take concierge's help to unload and secure the packet.

5 Related Work

In this paper we have advocated for the importance of focusing on just the last "100" yards of delivery. A number of prior works dealing in the last "mile" of delivery have explored parts of the problem we have outlined here and their findings are discussed below.

Non-Transfered Deliveries. In their survey of the last mile problem Boysen et al. [3] identified a number of challenges with systems which are based on single deliverers. For human-based services they found that drivers would have to undergo *pedestrian subtours* as they exited their vehicles to make the delivery and these subtours could become quite intricate in dense urban environments with limited parking or gated access. Furthermore, in the case of delays on the customer side where they were not home at reception time or were busy and unable to receive the delivery causes delays [1]. This forces a decision to either compromise the delivery schedule causing possibly more missed deliveries or to miss a potentially important customer delivery and have to redeliver at another point.

Robotics Piloting. While humans are almost always able to navigate their way through the last 100 yards this isn't necessarily true of robots. In their survey of the current problems facing robots Plank et al. [10] investigated the accessibility constraints on a number of different robot designs. They found that each city and town provided a unique challenge and that no one robot was fully suited to every task variant. The city of Pittsburgh recently ran a program allowing delivery robots to operate on their streets and took note of how humans interacted with the robots [17]. They found that humanizing the robots often promoted humans to assist the robots when they became stuck, lost, or blocked.

Visual Navigation. The environment of the last 100 yards is often quite different than that of the preceding mile. In an effort to expand the solution space of autonomous delivery drones from more rural to urban environments, Brunner et al. [4] built a purpose made prototype. They were able to successfully deliver packages straight to users' properties like balconies and porches which had been demarcated with an identifier stating where to drop off goods. Furthermore, having humans in an environment reveals another nuance to PILOT navigation. One way of dealing with this is spatial density functions proposed by Vega et al. [16]. These functions are especially nice since they seek to implement the same social rules of navigation that humans implement in society such as not walking between two people engaging with one another and respecting personal space. Respecting such norms will be essential to the success of PILOTs operating in such spaces.

6 Concluding Remarks

In this paper, we looked at the problem of navigating the last 100 yards in a constrained setup. We examined the scenarios of performing delivery in an apartment complex and helping a passengers connect with a driver at the airport. For the airport scenario, the human pilot is most suitable since it is a place with many people and cars moving around. We examined the limitation of the user pilot delivery as well as the challenges in a fully automated solution. Future work includes building a fully automated robotic cart as well as some of the associated issues.

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