Sharing Public Space with Robots: Following a Fleet of Delivery Robots on City Sidewalks

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Abstract

Robots on dense urban sidewalks enter environments in which space is contested. While prior work has described how bystanders and passersby accommodate delivery robots, we still lack a deeper understanding of what kind of problems emerge when autonomous robots enter a new area. This paper builds on 9 hours of fieldwork conducted during the early weeks of a delivery robot rollout in a European capital, characterized by a mixture of wide and narrow sidewalks. We describe emerging observations that highlight the contested and negotiated nature of these spaces, in which people make their trajectories readable, projecting where they will go next and establishing local traffic norms.

CCS Concepts

• **Human-centered computing → Field studies**.

Keywords

delivery robots, accommodation work, yielding behavior, social robot navigation, ethnomethodological conversation analysis

1 Introduction

Robots increasingly enter city streets as parts of public deployments. While HRI research has followed commercial deployments through field studies [1, 2, 12], it remains unclear how such studies can contribute to robot navigation problems [9], providing evidence for conceptual questions such as who should yield [17].

We report on emerging results from a project that follows a long-term trial deployment of a small fleet of robots in a European capital. The project aims to understand challenges to feed into regulatory and standardization efforts for public mobile robots. In this paper, we are particularly interested in documenting the very early stages of a fleet deployment, when most pedestrians are encountering the robots for the first time. We apply similar methods as established in prior ethnographic work on delivery robots [1, 12], video recording robots on their delivery journeys.

Our video recordings capture how the robots struggle to adhere to the local walking norms and expectations for negotiating and yielding space. As demonstrated in micro-sociological and inter-actional studies, strangers walking through the city establish local order, arranging themselves in recognizable ways on the street [7, 10, 19]. Our data show how robots challenge these human orders, ending up on a collision course with pedestrians. In several situations, the usable sidewalk narrows to a single lane, so that either the robot or the pedestrian has to stop or step aside from the sidewalk to create space for the other to pass.

Our emerging work offers two contributions. First, we present video-recorded examples of yielding behaviors on public streets, which can inform discussion in HRI of how yielding behaviors should be designed and theorized. Second, we discuss implications for social robot navigation and the presence of robots in shared spaces when robots challenge local walking norms.

2 Related Work

This study is based on three key research areas. First, we highlight prior work examining human-robot encounters on public streets, and specifically delivery robots. Second, we point towards the earlier work on walking norms in cities. Lastly, we show how studying robots in situ on public streets captures the emergent and unscripted interactions present in these environments.

2.1 Coordinating movement in human-human public interaction

Researchers in sociology and human geography have long been interested in studying behavior in public spaces. Goffman [5, 6] described in the 1960s how people move and encounter each other in public spaces. As video cameras became smaller, researchers could use them to document how people use urban infrastructure [21]

S. Ekman, J. Örtegren, K. M. Sieklucki, R. Tchou, L. Halvorsen, H. Pelikan

and how people communicate through the entire body, moving in and out of spatial formations [8] in public settings. Ethnomethodologists in particular have been interested in studying commonsense knowledge, exploring how people coordinate their movement in public space. Ryave and Schenkein [14] describe walking as an art, drawing attention to the "navigational problem", how strangers avoid bumping into each other when walking in public. Hester and Francis [7] note how people walk in "relational configurations", we can usually see easily whether people are walking alone, in a pair or as part of a larger group and typically lone walkers yield to people who are walking together. Watson [19] notes that in dense spaces such as train stations, people arrange themselves into a "file", with strangers ending up walking behind each other, forming a line, to smoothly move through space. This body of work demonstrates that human movement that may appear unpredictable and random at first glance is in fact highly organized. Aiming to understand how robots fit into this intricate organization, we are particularly interested in studying edge cases, when robots fail to adhere to human walking norms.

2.2 Social robot navigation

To build robots that can competently move among humans, they need to have some awareness of human walking practices and local norms [4, 9]. Torre et al. [17] framed social robot navigation as a game-theoretic coordination problem by investigating a "chicken race" scenario, in which a human and a robot approach each other on a collision course. Their findings show that people's willingness to yield is shaped by perceptions of the robot's anthropomorphism and autonomy, with participants swerving differently depending on whether they believed the robot was teleoperated or autonomous. This work demonstrates that navigation is not merely a computational problem of collision avoidance, but also a social coordination problem grounded in human expectations of robot agency. In a recent survey of social robot navigation, Mavrogiannis et al. [9] identify "limited understanding of human pedestrian behavior" as a fundamental barrier to designing socially competent systems. Significant gaps remain in understanding how robots and pedestrians negotiate yielding in real-world encounters.

2.3 Robots on public streets

A small body of empirical work sheds light on how people move around autonomous robots in public spaces. Pelikan et al. [12] examined delivery robots on UK streets, revealing how their mobility depends on human *accommodation work* (pedestrians routinely yield space, alter formations, and interrupt their own activities to let robots pass). Yu et al. [22] documented behaviors impossible to capture in laboratories: testing behaviors, robot bullying, and spontaneous assistance from bystanders. Weinberg et al. [20] observed a delivery robot and found pedestrians actively constructing explanations for the robot's purpose and behavior. Raab et al. [13] examined how pedestrians navigate around robots depending on whether they are distracted or not, showing how both robot design and movement patterns can effect pedestrian behavior.

Our study contributes to this emerging body of work by examining Torre's chicken problem on real streets: we are specifically interested in how yielding unfolds in practice.

3 Method and Theoretical Approach

This study followed the deployment of autonomous delivery robots in a central district of a European capital. The robots are operated by Starship Technologies and deliver groceries for an established quick-commerce company. The urban setting where the robots are deployed is one of the most populated areas in the city, characterized by highly frequented wide and narrow sidewalks dating from before cars were dominating cities. We followed a Walk-along with Robots (WawR) method as described by Cheon and Shin [1], where the researchers follow a robot on its entire delivery journey to document encounters with passersby.

3.1 Delivery robots

The Starship delivery robot is a six-wheeled, knee-height vehicle weighing around 35 kg, with sensors for autonomous navigation and independently moving wheels for curbs. It features lights and a cargo box. When ordering groceries via the app of an established local food delivery provider, robot delivery can be picked as an option. The robots run on sidewalks, occasionally crossing streets.

3.2 Fieldwork

The fieldwork was conducted during 9 hours while placing three strategically timed orders (11:00, 12:30, 17:30) to addresses chosen for both delivery feasibility (routes that are not too far) and anticipated complexity (areas and times likely to generate human-robot encounters). Each delivery was documented with two cameras, one continuously focusing on the robot, and another documenting the robot's immediate surroundings, often from across the street. In addition, we approached pedestrians for short semi-structured interviews, aiming for a variety of age groups and experiences. We took field notes to complement the video and interview data.

3.3 Using an EMCA approach

Our analysis is grounded in ethnomethodological conversation analysis (EMCA), following a similar approach as Pelikan et al. [12]. Following the EMCA research tradition, our aim is not to quantify observations, but rather to unpack the subtle ways in which interaction emerges as a situated accomplishment, which can be instructive for understanding social practices [15].

Video fragments capturing robot-pedestrian encounters were examined in detail to describe the interactional practices through which people orient to and accommodate robots, such as yielding, adjusting trajectories, or momentary pauses. This approach enabled us to investigate the visible coordination of movement, unpacking the subtle and embodied ways in which people accomplish encounters with robots in everyday urban settings. First, we identified moments when passersby yield to the robot. We selected fragments that capture a range of scenarios and environments, focusing on moments where coordination appeared to be problematic for further analysis in group data sessions [16]. Transcribing selected extracts as image sequences, we unpack how subtle movements contribute to action sequences that form the encounter.

Figure 1: Pedestrians encountering the robot on a wide sidewalk. Image 1: People walking in a file. 2: Robot on collision course. 3: Robot moving into the opposite file. 4: Pedestrian squeezing past the robot. See supplement for the entire video.

3.4 Ethics

Recording in public is permitted for research purposes in the country where we conducted the research. A risk assessment was completed in collaboration with the university lawyers. Video recordings focused on following the robots and the people who interacted with the robot. We blurred the recordings in post-processing to obscure faces and other potentially identifying features. During interviews with people on the street, we recorded voice only, after explicit verbal agreement from the passersby to be recorded. Participation in interviews was voluntary, and contact cards were shared for potential follow-up.

4 Analysis

In the following section, we will show four interactions that highlight challenges in the coordination work formed on contested narrow and wide sidewalks.

4.1 Driving on wide streets: Fitting into local walking norms

When walking in dense shared spaces, pedestrians typically self-organize into a line on one side of the sidewalk, referred to as "flow files" by Watson [19]. The fragment in Figure 1:1 shows how people walking in opposite directions arrange themselves on their right-hand side of the sidewalk to avoid intersecting trajectories. The delivery robot is not aligning with the flow files but instead moves in the middle of the street. When encountering obstacles the robot adjusts its direction. In Figure 1:2 the robot adjusts its trajectory to the left, probably in response to a café sign placed on the right. The robot moves into the oncoming flow of pedestrians, ending up on a collision course with a pedestrian. Avoiding a collision, the robot suddenly brakes and the pedestrian continues walking. The robot keeps driving along the left side of the sidewalk, moving in the opposite direction of the flow of pedestrians.

Just a few meters on, the robot encounters the next pedestrian as shown in Figure 1:3. As they get closer, the pedestrian aligns with the far left boundary of the sidewalk (their right hand side). The pedestrian squeezes in between a parked vehicle and the robot, as shown in Figure 14, demonstrating a strong orientation to walking to the right, and visibly manifesting their expectation that the robot should also stick to the right, in this case close to the buildings.

The video extract illustrates that pedestrians, typically strangers, carefully coordinate their walking into flow files. Notably, there is no law stating that people should walk to the right – the national traffic agency states only that "it is not regulated on which side to walk. Here it is important to show mutual consideration" [18]. In line with what has been described in decades of micro-sociologic and interaction analytic research, people establish situated local orders and arrange themselves in a walking file. The robot fails to acknowledge the emerging local order and ends up not only as an obstacle that pedestrians have to squeeze past, but looks as if it were actively setting itself up on a collision course, heading for specific pedestrians.

On a different occasion, a pedestrian we interviewed in passing expressed discontent with how the robots behaved in a situation similar to the example presented in Figure 1:1, saying "It doesn't feel like it knows where to go. That's why I think it should just stop, let people pass by, and then move on." In fact, the robot rarely actively yields; instead it keeps moving until it gets too close to a pedestrian, which is when it reliably initiates an emergency stop. Torre et al. [17] asked in a simulation study whether humans or robots should swerve first, here we can see how pedestrians negotiate on a real sidewalk who should give way. Since the robots are slow to turn, pedestrians may have to be extra careful. One pedestrian told us: "Yesterday I almost got run over by it (...) I walked with my face in my phone. Maybe it was half my fault." The robot's movements and stops are often a bit too late for pedestrians to smoothly coordinate with, and may become particularly problematic when pedestrians are distracted.

4.2 Passing down narrow sidewalks: When space is contested

The negotiation of space becomes even more delicate on narrow streets, where there is only room for one person to pass at a time. In such spaces, people typically negotiate space by stopping on their way, or briefly stepping onto the road, effectively offering space to let others pass by. Figure 2 shows that this is a particularly challenging environment for robots to operate in, especially in the presence of additional obstacles.

In Figure 2:1, the robot encounters a parked forklift parked, partially blocking the sidewalk, which is already narrow. The robot stops, but the sudden movement causes the forklift to move and bump into the robot. An approaching pedestrian sees the collision and adjusts their path, walking closer to the buildings. In Figure 2:2, the pedestrian steps into a doorway, effectively making space for the robot to pass through. The robot moves slowly, turns away from the forklift and into the sidewalk, where it stops. Eventually, the pedestrian starts moving and squeezes past the robot.

Figure 2: Negotiating space on narrow sidewalks. Image 1: The robot encounters a forklift. 2: Pedestrian giving way by stepping into a door frame. 3: Robot obstructing the sidewalk as two pedestrians approach. See supplement for the entire video.

This example shows how the robot displays a certain direction through its movement and orientation, which can be read as the robot claiming space. Yet, when the pedestrian steps aside and offers space, the robot is unable to move on the offered path. Instead, it remains stationary, leaving little space for the pedestrian to pass.

Stopping and stepping aside are natural parts of human spatial negotiation. In our street interviews, one pedestrian suggested: "I think it could have stood still until all the people were out of the way." Another pedestrian noted: "Well, you go around people", drawing attention to the mutual coordination work involved in these encounters. When turning and replanning its path, the robot simultaneously displays a direction. Yet, the robot is often too slow to act on its claimed space, putting the burden of resolving the situations on humans who may have offered space in the first place.

In some cases, there is no excess space for squeezing past the robot. Figure 2:3 illustrates how the robot stops on a narrow sidewalk lined with large parcels that occupy half of the width of the sidewalk that is designated as a temporary loading zone. Two pedestrians approach the robot walking side by side. Before entering the obstructed area, both pedestrians stop and look at the robot. Like the pedestrian in the previous example, they step to the side, offering space. When the robot remains stationary, they step off the pavement and continue walking on the road instead.

In this fragment, there is no space alongside the stationary robot to squeeze past. Acknowledging that the robot cannot yield, the pedestrians are left with no other option than to yield to the robot.

5 Concluding Discussion

We have shown how delivery robots entering a dense city environment struggle with local walking norms, ending up challenging them by intersecting with pedestrians' flow files. Furthermore, delivery robots struggle to read offers for space on narrow sidewalks, forcing pedestrians to accommodate the robot by removing themselves from the sidewalk, stepping into doorways or onto the road.

5.1 Who is yielding?

Our observations suggest that the question of who should yield does not have a binary answer. The robot adjusts its path and stops; pedestrians pause, step into doorways, and leave the sidewalk. Both parties yield, but with different consequences: when a pedestrian yields, the encounter is typically resolved; when the robot stops, the encounter is left suspended. Stopping is not equivalent to yielding

space. In many cases, pedestrians perform accommodating actions to resolve the encounter with the robot, confirming prior work [12].

What emerges is an asymmetry: the robot maintains its trajectory while pedestrians adjust around it. As shown in Figure 2, pedestrians offer space by visibly stepping out of the way *before* getting close to the robot. While such actions are clearly legible as offers for other humans, they remain invisible to the robot. In turn, the robot does not appear to assert right-of-way through recognizable social signals – rather, its inflexibility forces the interpretive and practical burden onto pedestrians.

Torre et al. [17] framed social navigation as a "chicken game", in which either party swerves first, but this framing assumes a symmetry that may not hold in practice. Our observations suggest that pedestrians consistently bear the burden to adjust, while the robot's movement remains rigid. Whether this pattern reflects robot design limitations, pedestrian expectations, or some interaction between them remains a question for future studies, but the practical consequence is clear: encounters are resolved through human flexibility, not mutual negotiation.

5.2 Navigating local traffic norms

Our work highlights that beyond established traffic *rules* for the street, there are local traffic *norms* that emerge on crowded sidewalks. Pedestrians demonstrate in their behavior that they assume robots to comply with these norms, which robots currently cannot do. Our work raises questions about how robot design could support local public norms. Should a robot always "keep right"? Should a robot attach itself to the end of a flow file? To what extent should a robot follow local traffic norms at all?

The emerging field of social robot navigation currently focuses on technical implementations, with simulations modeling individual users. Our work highlights the need for better methods to integrate sociological insights into robot design for public spaces. Our work contributes to efforts to make such translations [11] but also raises broader questions about what areas are suitable for robot deployment [3]. Future work may look into how HRI researchers can practically support cities in navigating robot deployments.

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