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Humans and robots coping with crisis – Starship, Covid-19 and urban robotics in an unpredictable world

Miguel Valdez, Matthew Cook., and Stephen Potter

Abstract— In 2018 “Starship” grocery delivery robots were first introduced in Milton Keynes (MK), a new town in England, to automate a task that is difficult to perform in a cost-effective manner by humans – that of on-demand grocery delivery. Two years later the Covid-19 pandemic rendered routine activities such as delivering groceries or visiting the supermarket unexpectedly unsafe. The ability of robots to operate in environments that are dangerous for humans was brought into sharp relief by the Covid-19 pandemic but it may also be relevant in other crisis situations such as those that may be caused by heat waves, blizzards and other extreme events associated with climate change. Drawing on a case study of Starship robots in MK, this contribution investigates the potential of robotic and autonomous systems to provide cities with tools for coping with such unexpected situations.

I. INTRODUCTION

The introduction of robots in urban spaces has considerable transformative potential and delivers technological capabilities and capacities beyond human abilities and existing infrastructural possibilities [1], automating and augmenting complex urban tasks that are unattractive, repetitive or labour intensive as well as those that are highly complex or dangerous [2]. In 2018 “Starship” grocery delivery robots were first introduced in Milton Keynes (MK), a new town in England, to automate a task that is difficult to perform in a cost-effective manner by humans – that of on-demand grocery delivery. Two years later the Covid-19 pandemic rendered routine activities such as delivering groceries or visiting the supermarket unexpectedly unsafe. The service performed by grocery delivery robots, which was merely intended to be convenient and cost-effective, unexpectedly became the safe alternative to a task that was potentially too dangerous for humans to perform. The ability of robots to operate in environments that are dangerous for humans was indeed brought into sharp relief by the Covid-19 pandemic but it is also likely to be relevant in other crisis situations [3] such as those that may be caused by heat waves, blizzards and other extreme events associated with climate change. Drawing on a case study of Starship robots in MK, this contribution investigates the potential of robotic and autonomous systems to provide cities with tools for coping with such unexpected situations.

Urban robots are the physical agents of AI-driven autonomous systems designed to make decisions in real time and negotiate complicated tasks in dynamic contexts. Urban AIs are designed for learning, dealing with complex

situations, making decisions on the basis of incomplete information, handling uncertainty and responding to changing situations in real time in pursuit of predetermined goals [4]. There is a significant interaction between the emerging robotic/autonomous urbanism and the now well-established smart urbanism [4]. As such, robotic urbanism inherits a cybernetic logic which uses information and communication technologies to react to unfolding events, thus monitoring, managing and optimising city flows and processes through the use of real-time analytics [5] [2]. When faced with unexpected conditions that interrupt urban life and the myriad flows and operations required to support it, the ability to cope and respond in real time to circumstances that cannot be controlled becomes crucial [6]. The cybernetic logics of AI and urban robotics hold potential to improve cities’ capacity to cope.

We therefore critically review the development of urban robotics in MK (an early adopter of this technology), paying particular attention to how it formed part of the response of the city to an unexpected crisis – the Covid-19 pandemic. We consider the role of urban robots and their potential to provide cities with tools to better cope with future pandemics and similar crises such as extreme weather events. The case study presented in the next section traces the introduction of the Starship robots in MK starting in 2018 but with particular attention to their performance during the Covid-19 pandemic of 2020-2021. The rapid spread of Covid-19 induced “panic buying” of groceries and consequently conventional delivery services were overwhelmed. Households shielding, self-isolating or without a car lacked convenient and safe access to basic groceries and supplies. The crisis revealed robots as part of a network of complementary commercial, governmental and volunteer-led approaches for supporting the basic societal function of getting groceries to households.

II. CASE STUDY

A. Urban robots in MK before the pandemic

Starship Technologies was founded in 2014 and produced its first prototype robot the same year. The current iteration of the 6-wheeled robot measures approximately 56 x 68 x 56 cm (or 125 cm on account of the bright antenna added for visibility). The robot weighs approximately 27 kg and it can transport up to 10 kg in its lockable cargo compartment. With an operating speed of 6 km/h it is suitable for on-demand short distance deliveries organised around local hubs where the robots are loaded, recharged, and cleaned when they return from a delivery.

Customers place orders through a mobile phone application which can be used to track the movement of the robot. Once the robot arrives to the destination indicated by the user, they receive an alert so they can meet the robot and

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unlock its cargo compartment (Fig 1). Starship robots therefore perform a similar function to that of a bicycle courier but, when deployed at scale, they are expected to cost 10 to 15 times less than other local delivery alternatives [7] [8]. The service currently operates under a flat fee of 0.99 GBP per delivery. The pricing scheme was temporarily changed at the height of the pandemic to prevent demand from exceeding the capabilities of the Starship fleet, with the service operating under a variable pricing scheme. The company advised that: “service fees will be lower when fewer people are requesting deliveries, and higher when lots of people are requesting deliveries. Deliveries that are further away and take longer may at times be priced higher than deliveries that are nearer” [9].

Autonomous operation of the robots is made possible by machine learning through neural networks [10] which allow them to navigate their surroundings, detect real-time changes (including the change of traffic lights as well as the movement of pedestrians and cars) and adapt to major changes in their environment (for example, road closures or new constructions). An array of 10 cameras and radars provide inputs to the trainable neural network, which over time becomes better able to create an internal representation of the locations in space of entities such as pedestrians, cars, cyclists, dogs on leashes and navigational landmarks. Computations that need a rapid response are performed on-board, while those that are less time-sensitive are offloaded to servers in the cloud [11]. Robots can therefore pool their collective knowledge to create a unified 3D map of a given area, which they use to identify and navigate the shortest and the safest path between their hub and their destinations. Collective artificial intelligence is also used to orchestrate fleet operations - deciding which robot should do which delivery based on predictions about the expected demand, the availability of robots and the expected battery state after each journey [11].

Figure 1. A mobile phone application allows users to request the delivery of groceries from supermarkets or local businesses in their area.

When Starship deliveries were first envisioned, the legal status of unaccompanied autonomous robots in urban environments was unclear owing to a lack of regulations and legal precedent [7]. The company sought to cultivate connections with industry bodies, becoming embedded within the autonomous and connected vehicle community in the UK, as well as with innovation-friendly local authorities [12]. Milton Keynes, a new town in England with a population of approximately 250,000 residents and located some 100 kilometres north of London, was selected as the site for the first commercial deployment of delivery robots operating autonomously in an urban setting. Operations started in April 2018.

The local authority in MK was willing to work with a new technology which they acknowledged was not yet fully proven, because they considered that it had potential to support their economic goals (job creation), environmental goals (replacing car trips or van deliveries) and social goals, as they anticipated that the robots would be useful for providing deliveries to households that suffered from reduced personal mobility [13]. MK was a suitable location for the pioneering deployment of autonomous robots in an urban environment on account of its low density and its extensive network of segregated paths for pedestrians and cyclists, which were relatively safe and easy for AIs to navigate [14]. Shortly after the launch in MK, Starship robots were introduced to corporate and university campus across the US and Europe, which also provided a safe environment for the AIs. The use of delivery robots in dense urban centres would be potentially more efficient and cost effective on account of the customer density, with more potential customers living within the area served by a delivery hub [15]. However, further developments in AI are needed before the deployment of delivery robots in high-density urban centres can be realistically considered. Low-density footpaths such as those available in MK make it possible for people to make their way around robots when they stop, as they often do when faced with an uncertain or unexpected situation. However, if a robot were to stop in a crowded pavement in London or a sidewalk in New York it would cause considerable aggravation and risk for pedestrians [16]. Classical mapping and navigation algorithms are considered insufficient for safe operation of robots around pedestrians in urban settings, which are likely to require consideration of the sometimes random and sometimes linear flows of pedestrians [17] (so that robots can learn to either "go with the flow" or "get out of the way") as well as understanding of the social and psychological constraints on pedestrian behaviour and existing cultural conventions of behaviour in public space [18] [19]. However, the low density of MK, which is comparable to that of suburban areas of larger cities, made it possible for pedestrians to adapt to the behaviour of the robots, which is seen as non-threatening, helpful, friendly and endearing even as they occasionally struggled to complete their assigned task [20]. As the wide paths of MK make it easy for robots and pedestrians to coexist, Starship notes that 70% of pedestrians do not pay any attention to the robots, with most of the rest reacting positively to them [15]. Consequently, the robots were rapidly accepted by users in MK and they were considered part of its everyday life, as even non-users would often see them making their way along

pavements or footpaths and kids would try to pet them or feed them [21].

While the company acknowledged that some early users were attracted by the novelty of the service, they also identified regular users who appreciated the convenience. By April 2019, 50,000 deliveries had been completed and the company was aware of users who had placed more than 100 orders through the year [22]. 11 months later, on March 13th, 2020, the company met its next milestone having reached 100,000 deliveries across MK and announced a major expansion in the city centre. Three days later the United Kingdom unexpectedly entered its first Covid-19 lockdown, with the health secretary announcing that all unnecessary social contact should cease. The British population was instructed to stay home, all non-essential shops and services were ordered to close and those at the highest risk of severe complications from Covid-19 were advised to follow special shielding measures. MK, like so many other cities across the world, was faced with a major disruption of key aspects of urban life including transport and food provision [23].

B. Robots supporting the response to a crisis

Uncertainty regarding the duration of the stay-at-home orders and the capacity of supply chains to overcome the disruptions caused by Covid-19 in the early stage of the pandemic provided a rationale for consumers to build up their stocks of groceries and basic household supplies. In addition, knowledge that other consumers were in a similar position caused an undesirable feedback loop with large numbers of consumers engaging in what can be described as hoarding and panic buying [24]. Traditional online grocery delivery services were affected by the disruption. Delivery drivers were working extended hours and supermarkets were implementing restricted queueing systems as well as releasing additional delivery slots but they still struggled to cope with the sudden growth in demand [25] [26]. In consequence, customers attempting to place an order would often be informed that they would have a waiting time of several weeks before they would be able to schedule a delivery [27]. The disruption to online grocery deliveries was particularly problematic for vulnerable individuals including older adults, people with underlying health conditions or those less able to move [27], who often rely on home deliveries in order to remain independent [28]. The flooding of online grocery delivery services added a level of inconvenience or even danger for vulnerable people who, despite attempts by supermarkets to allocate additional slots, were unable to secure deliveries when services were inundated by requests [29]. Consequently, 55% of disabled adults surveyed by the Office for National Statistics reported difficulties accessing groceries, medication and essentials [30] - this included vulnerable people who were not considered vulnerable enough to receive government or community support, as well as people who officially qualified for assistance but struggled to secure online deliveries and access other forms of support [31]. A YouGov survey on food insecurity commissioned by the Food Foundation found that more than three million people reported going hungry in the first three weeks of the UK's Covid-19 lockdown [32]. Approximately 8% of the adults in the UK advised to self-isolate experienced food insecurity directly attributable to isolation - that is, food was available

and the respondents had financial access to it but were unable to go out and did not have any other way to get the food they needed [33].

In contrast to traditional online delivery services, Starship continued operations in MK during the pandemic with very little disruption. Company executives state that the number of orders doubled virtually overnight and the fleet was working non-stop 14 hours a day [34] but the service remained able to offer same-day deliveries. Although the service had not been specifically designed for that purpose, a robot-based service which avoided face to face contact proved to be well suited for delivering groceries to those housebound, shielding or self-isolating on account of the pandemic. Disability advocacy groups included Starship deliveries, where available, in guidance for clinically vulnerable and extremely vulnerable groups [35]. A decision was made to expand the coverage and capacity of the service as quickly as possible, so that the number of robots available for deliveries in Milton Keynes doubled from 30 at the beginning of the pandemic in March 2020 to 70 by April and 100 by July of the same year.

Achieving a 300% increase in capacity in a matter of weeks would have been difficult for vehicle-based and human-based services on account of the cost and difficulty of acquiring new vehicles in the middle of a pandemic which was severely affecting supply chains in addition to the difficulties in recruiting and training staff on a short notice. The case of MK suggests that AI-driven robotic systems can be reconfigured and have the ability to rapidly adapt and respond to crisis situations. The Starship programme in MK also benefited from a fortuitous contingency - many Starship robots in other locations were predominantly deployed in university campuses which were closed due to the pandemic, leaving them available for redeployment to MK. Such a rapid redeployment was facilitated by the AI powering the robots. New additions to the fleet could be readily connected to the servers storing the aggregated navigational knowledge of the collective intelligence and could be readily handled by the AI system orchestrating fleet operations.

C. Robots and vulnerable populations

Starship robots completed over 1.5 million deliveries through the duration of the pandemic [36]. The rapid growth in demand, which underwent a 900% increase relative to its pre-pandemic level, suggests that the robots performed a useful role during the crisis. Starship technologies frames contactless delivery as one of the most reliable ways to protect vulnerable populations and enable social distancing during the COVID-19 pandemic [36], a view supported by commercial partners [37], investors [38] and local authorities [13] [39]. However, the benefits provided by the robots were not evenly distributed. Urban robots, like so many other urban technologies, have the potential to reinforce social and spatial inequalities [2]. Such inequalities were present to some degree in MK according to interviews with local community organisations and support groups. Spatial inequalities were present because the robots were only available in selected areas of MK, with a tendency to cover more affluent areas and neglect those that were more marginalised. Additionally, many members of vulnerable groups, such as those subsisting on a disability allowance, would not be able to pay the variable delivery fee on a

regular basis. Other vulnerable individuals who would have liked to rely on the robots during the pandemic were unable to use them because they were not able to use the mobile phone application, as was the case for example for less tech-savvy older adults or for the visually impaired. Vulnerable populations are often less connected to the internet and less able to use online resources, particularly if they are older, have lower incomes, or live alone [29] [31]. The robots are also unsuitable for some users with physical and mobility impairments. For instance, wheelchair users may find it difficult to reach and unload the robot.

However, even if a robotic system is not a suitable replacement for voluntary organisations, community groups and other components of the social safety net, they can usefully complement it and increase its ability to cope with unexpected crisis. Various initiatives and responses by governmental, commercial and community organisations demonstrated distinct capabilities, strengths and weaknesses and served (or failed to serve) distinct groups at various points through the crisis. Although the safety network provided by robots was not equally available to everyone who would have needed it, it had the distinct advantage of being able to adapt and respond to an unexpected situation in real time, thus providing a crucial safety net during the early weeks of the pandemic when many vulnerable individuals experienced food insecurity [33] [32]. In contrast, national and local authorities were not well suited to take rapid action when faced with an unprecedented situation. Weeks after the beginning of the lockdown, local authorities were still waiting for guidance from national government and did not have access to the full lists of people identified as extremely vulnerable in their area [40]. Community and volunteer organisations were also largely caught by surprise by the rapidly changing situation, with a study conducted by the Research Institute for Disabled Consumers [41] finding that 50% of the respondents were unable to receive support previously available to them during the early weeks of the pandemic [31]. Interviews of MK-based volunteers confirms that some organisations were able to respond in a matter of days but for others it was weeks before they could adapt to the new situation and provide safe and effective support to those who needed it. Volunteer and community organisations benefited from their pre-existing knowledge of vulnerable individuals [42] and were able to reach and support people that robots could not reach, but they could not easily identify and reach people who had not considered themselves vulnerable before the pandemic. Those same individuals were potentially excluded from government initiatives intended to ensure that vulnerable people could get food [43], which were subject to triage [44] and in consequence excluded some individuals who considered themselves vulnerable but were not considered a priority. People with manageable health conditions (e.g., immune deficiencies, asthma) who were able to live independently under ordinary circumstances unexpectedly found themselves vulnerable, housebound and unfamiliar with the support networks that could have helped them, but many of them were able to access the autonomous robot delivery system. Urban responses to the developing crisis can therefore be conceptualised as a multi-layered safety net, with each layer having different gaps or potential points of failure. For some vulnerable households, access to autonomously delivered groceries provided a first safety net

before the other layers could be set in place. In other cases, the robots provided one last extra layer for vulnerable individuals who had slipped through the cracks in all the others, for example because they were not eligible for government support and were not aware of community organisations.

III. DISCUSSION AND CONCLUSIONS

The case study, tracing the development of urban robotics in an early-adopting new town and the contribution of autonomous robots as part of the response to an unexpected crisis, reveals that autonomous robot systems can effectively provide cities with tools to better cope with future pandemics and may also support key urban functions in other crisis scenarios. For instance, Starship robots were able to continue in operation during the major weather disruption caused by Storm Emma in 2018 [10] [45]. Global climate change is causing increasingly unpredictable extreme weather events including for example floods, blizzards, storms and heat waves (Fig. 2). In consequence, cities need a large array of options for coping with the unexpected [6]. Urban robots are likely to play an important role in making cities preventively better prepared. The impact of robots has often been limited in scope and reliability when they have been pushed to their limits in crisis scenarios [3] but the case study reveals some characteristics of autonomous robot systems that merit further investigation. The case of MK suggests that robots are better able to support cities when they are considered as part of a complex urban network, a combination of humans, technologies and infrastructures which, together, are better able to cope with the unexpected and jointly sustain the flows and operations which define urban life [2].

Figure 2. Starship robots have been tested for functionality in different weather conditions including rain, snow and ice.

First, the case study reveals that urban robots made the city better able to cope with the unexpected not because they were less prone to failure than other systems, but because their points of failure were different. A city that relied exclusively on robots for all its logistics would not necessarily be more resilient than one relying exclusively on delivery drivers. When a critical societal function (e.g., ensuring that groceries can reach households) is structured by a small number of practices, capabilities and technologies (e.g., buyers driving to stores or by couriers from the stores driving to households) there is a risk that when faced with a shock in their environment they will all experience highly correlated and destabilising failures [46] [47]. Urban robots therefore can make cities better able to cope with the unexpected when they initiate a shift away from technical and institutional monocultures. To achieve that end, it is important that they are not framed as the sole solution to a given urban challenge (potentially becoming a monoculture of their own) but they can usefully become part of a network of complementary commercial, governmental and volunteer-led approaches for supporting key urban functions such as that of getting groceries to households.

The case also reveals that the robots were able to support the city during a crisis because they were already embedded in its infrastructures, institutions and practices. One of the defining characteristics of cybernetic systems is their ability to organise themselves to maintain stability or homeostasis. In the case of MK, the robots' ability to respond and adapt in real time was only possible because the robots were already part of the urban system, thus increasing its cybernetic capabilities. When Covid-19 threatened to disrupt key urban functions in MK, the autonomous robot system already had been deployed at scale, was already in motion and had been trained to self-organise and maintain efficient operations in changing circumstances. Also, importantly, local authorities, users and other members of the extended actor network needed to sustain the system were already familiar with it. In the case of MK, the embeddedness required to make robots effective in time of crisis was only possible because the autonomous robot system was not designed or framed as a disaster-response mechanism. The robots were part of a useful everyday infrastructure, and they were also considered part of the unique culture of the city and seen as members of a human-robot community that proved to be surprisingly adaptable when faced with unprecedented times.

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