Exploring temporal pleats and folds: the role of Urban AI and Robotics in reinvigorating the cyborg city

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Abstract:

In this chapter, the rapid response of a fleet of "Starship" delivery robots during the Covid 19 pandemic becomes an entry point for investigating cybernetic, or rather cybernetic and organic (or cyborg) (re)configurations developing around urban robotics. The notion of the "cyborg city" is used to investigate urban spaces where humans and machines interface with each other, undergoing processes of joint learning and distributed cognition as machines learn to be in the city and cities learn to live with intelligent machines. Ultimately, we investigate cyborg cities in terms of the (re)configurations that take place as robots and humans become enmeshed in rapidly changing configurations. The case suggests that the presence of autonomous robots and their integration into the urban fabric has potential to make cities more resourceful and better able to respond to shocks, as prefigured by early proponents of cyborg urbanism. However, it also suggests the presence of AI-driven robots is not by itself sufficient to produce such (re)configurations- here, renewed intensities of human-robot interactions resulted from joint responses to a sudden shock. The resulting human and non-human configurations persisted after the crisis, potentially revealing new ways of living with AI in the city.

1 Introduction

Recent developments in AI and machine learning have made it possible to deploy robots in cities. Initial experiments already demonstrate considerable transformative potential as urban robots deliver technological capabilities and capacities beyond human abilities and existing infrastructural possibilities (While et al., 2020), automating and augmenting complex urban tasks that are unattractive, repetitive or labour intensive as well as those that are highly complex or dangerous (Macrorie et al., 2021). Such urban developments call for increased attention to the ways in which they become embedded in contingent configurations that include not only robots but also humans, institutions, infrastructures and the myriad of entities and encounters that constitute the urban (Macrorie et al., 2021; While et al.,2021). Drawing on case study research focused on grocery delivery robots in an urban setting, this chapter examines the cyborg urbanisms which emerge from the intensification of robotic and human interactions in unscripted, unpredictable urban contexts. As such, it contributes to a body of research on the highly contingent, spatially uneven and socially selective processes of robotic urban experimentation (While et al., 2021; Macrorie et al., 2021; Sumartojo & Lugli, 2021).

In 2020 the Covid-19 pandemic rendered simple tasks such as visiting the supermarket to shop for groceries unsafe due to the high risk of contagion. In Milton Keynes (a city located in South East of England) the “Starship” robot grocery delivery service, became a safe way to complete this task, one which at the time was potentially too dangerous for humans to complete. Such disruptive events reveal aspects of urban life that would otherwise remain invisible, with breakdowns bringing fleeting visibility to the complex practices and technologies that continuously bring urban life into being (Graham, 2010). In this instance, the impacts of Covid19 and disruption to everyday life draw attention to renewed intensities of cyborg urbanism arising from robot-human interactions in certain urban contexts, with advances in AI and robotics reaching a threshold, anticipated by the founders of cybernetics, with potential to transform urban life.

The case study of the “Starship” delivery robot service in the Covid 19 pandemic set out below interrogates the cybernetic, or rather cybernetic and organic (or cyborg) (re)configurations developing around urban robotics. It suggests that the presence of autonomous robots and their integration into the urban fabric has potential to make cities more adaptable and better able to respond to unexpected shocks, as prefigured by early proponents of cyborg urbanism. However, it also suggests the presence of AI-driven robots is not by itself sufficient to produce such cyborg urbanisms- it requires an intensity of human-robot interactions through place-based processes of interfacing, learning and (re)configuration, with the moment of crisis potentially spurring the intensities required to transition to new ways of living with AI in the city.

2 New intensities of cyborg urbanism

Recent developments in urban robotics can be seen as renewed intensities of ways of thinking about humans and machines first developed in the context of the second world war and further developed in the aftermath of the cold war. The foundations of cybernetics, established as scientists used feedback loops to chart missile trajectories, were later extended to systems with the ability to sense their environment and respond to changes to achieve and maintain a desired state (Wiener, 1954; Bowker, 1993). The notion of the cyborg, a cybernetically augmented organism with the ability to adapt to unpredictable and potentially dangerous environments, emerged in the context of the cold war and the space race (Clynes & Kline, 1960). As the cold war started to wind down the notion of the cyborg was repurposed as a metaphor to draw attention to the increasingly blurred boundaries separating humans and machines (Haraway, 1991). Here, its application in urban contexts is of particular interest (Gandy, 2005). The notion of the cyborg became not so much a metaphor for understanding human-machine entanglements in urban contexts, but a diagram for prefiguring urban spaces as data flows to be sensed, visualised, modelled and scientifically optimised in real time (Marvin & Luque-Ayala, 2017).

Early attempts to bring cyborg urbanisms into practice were abandoned in the mid-1970s as the computing techniques imported from military operations proved ineffective in the urban domain (Marvin and Luque-Ayala, 2017) but recent advances in AI have renewed potential to transform cities and give rise to cyborg configurations. In the absence of AI, robots are comparable to the clockwork automata of the XVII century - incapable of making decisions of their own, their actions entirely dictated by sequences fixed by humans beforehand (Wiener, 1948). 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 (Cugurullo, 2019), thus introducing a cybernetic dimension to the city. Consequently, aspects of urban life that were previously automated (i.e., following pre-determined sequences, automaton-like) can now be adaptive and autonomous. Such transitions from the automated to the autonomous city (Cugurullo, 2019; 2021) are crucial but not sufficient to give rise to cyborg configurations in the city. When cybernetic machines are deployed in urban environments, which are unscripted, contingent and organic, the boundaries between cybernetic and organic systems are blurred. The interactions of autonomous robots and humans become entangled in the complex environment and systems that define urban life, there is increased potential for cities to behave as self-regulating, self-reconfiguring human-machine systems- in other words, cities may become cyborgs

The cyborg, as an entity first envisioned in the context of the cold war, is defined by its ability to use cybernetic and organic elements to adapt to unpredictable, potentially hostile environments and maintain equilibrium and autonomous control (Clynes & Kline, 1960; Tomas, 1995). Here we argue that developments of cyborg configurations at an urban level are not the result of linear advancements up a ladder of progress, but better understood as variations in intensity which, under certain conditions, may cross nonlinear critical thresholds. We draw on a topological, folded conception of history (Rosol, 2021; De Landa, 2000; Bingham & Thrift, 2000), where distant events, theories or practices can unexpectedly appear very near as time is folded like patterns on a folded handkerchief. The case study presented in this chapter suggests that unexpected shocks, such as the one caused by the Covid pandemic, create folds or connections linking the present time to the tensions and uncertainties of the wartime conditions that gave rise to the cyborg. Such tensions, in turn, provide the spark needed to intensify human-robot interactions and cross a boundary that goes beyond the autonomous city and into cyborg urbanisms.

Cyborg cities are defined by human-robot interaction in complex, unpredictable contexts. The cyber- prefix has been associated with various forms of virtuality (e.g., the "cyberspace") but the idea of the cyborg is closely associated with situated knowledges, corporeal experiences of space and the underlying materialities of machines and humans (Haraway, 1991; Gandy, 2005). In this chapter, cyborg cities are investigated as places where humans and machines interface with each other, undergo processes of joint learning and distributed cognition as machines learn to be in the city and cities learn to live with the machines and, ultimately, we investigate cyborg cities in terms of the (re)configurations that take place as robots and humans become enmeshed in rapidly changing configurations.

To this end, the case study traces the introduction of Starship robots in MK starting in 2018 and cybernetically enhanced response to the Covid pandemic in 2020 and 2021, particularly during the first ‘lock down’ in the UK.

3.1 Case Study – humans and robots in complex times

Milton Keynes (MK) is a new town in England with a population of approximately 250,000 residents and located some 100 kilometres north of London. Starship robots were launched there in 2018 (Fig 1). Starship robots can transport up to 10 kg in a lockable cargo compartment, have a top speed of 6 km/h and can navigate urban environments autonomously, making them suitable for on-demand last-mile delivery services. The Starship service is organised around local hubs where the robots are loaded, recharged and cleaned when they return from a delivery.

<Figure 1 here>

<**Caption to read: Figure 1 – A robot using MK’s “Redway” network of cycle paths to navigate the city autonomously and deliver groceries to users of the Starship service from supermarkets or local businesses in their area. Source: Author’s original** >

Like so many other cities across the world, in the pandemic MK was faced with a major disruption of key aspects of urban life including transport and food provision (Boons et al., 2021). The British population was instructed to stay home, 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 shielding measures. Uncertainty regarding the duration of the stay-at-home orders and the capacity of supply chains to overcome the disruptions caused by the pandemic provided a rationale for consumers to build up their stocks of groceries and household supplies, engaging in what can be described as panic buying (O’Connell et al., 2021). Customers visiting supermarkets risked contagion, experienced long queues and found empty shelves. Online grocery delivery services were also affected by the disruption. Delivery drivers worked extended hours and supermarkets implemented virtual queueing systems but still struggled to cope with the sudden growth in demand (BBC News, 2021; DEFRA, 2020). Consequently, customers attempting to place an order would often be face waiting times of several weeks before receiving their groceries (Hobbs, 2020). In contrast, Starship continued operations in MK during the pandemic with very little disruption. 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.

3.2 – Analysis

Data collection supported by the Open University's Coronavirus rapid response fund focused on interviews with volunteers and representatives of community organisations supporting vulnerable populations during the crisis, as well as representatives from vulnerable groups. Researchers also engaged in socially distanced participant observation through various stages of the pandemic, paying attention to the interactions of robots, pedestrians, vehicles, pets and several other unpredictable elements that constitute the urban. The research also draws on a documentary corpus including newspaper articles, trade literature, policy documents and transcripts from policy debates in the United Kingdom, with some of the selected documents debating the introduction of robots in the urban realm and others debating their role in the response to the pandemic.

Data were analysed under themes emerging from iterative engagement between data and matters of concern identified in the developing agenda for research on urban AI and robotics (Macrorie et al., 2021; While et al., 2021; Yigitcanlar & Cugurullo, 2020; Fourcade & Johns, 2020; Hasse, 2019). Theme selection was informed by a relational sensitivity to the urban geographies of robotic and autonomous systems and as such attention was centred on the place-based interactions of humans, robots and urban configurations. Specifically, the remainder of the case study interrogates the situated interactions of robots and humans and their joint response to a crisis in terms of the following themes: Encounters and interfaces, Learning machines and distributed cognition, and (Re)configurations. A discussion of the ultimate effects and outcomes of the resulting (re)configurations is then presented as a conclusion to the case study.

Encounters and interfaces

Urban robots must negotiate complex environments, balancing the demands of their assigned tasks with the rights of other users of the public realm (While et al, 2021). Consequently, cities where robots are deployed become places for meaningful encounters which are contingent and take place in contexts where neither humans nor robots can know precisely what will happen next. Such encounters give rise to unscripted forms of human-machine interfacing that make urban robots parts of 'emergent assemblages more than stable entities' (Bissell & Del Casino, 2017:439; quoted in Sumartojo & Lugli, 2021). Here, the word 'interface' is used in a broad sense, referring to any point where two entities meet and interact, as human-robot interactions are not exclusively or even predominantly directed by the on-screen interfaces of the computer or mobile phone applications through which robots might be controlled. Humans and robots may interface with each other physically, for instance, as well as affectively, developing trust and understanding which allows them to effectively share an urban environment - or failing to do so (Sumartojo & Lugli, 2021). With each encounter between humans and robots, meanings about automation and technology are (re)created (Yeo & Lin, 2020).

In the case of MK, the nature of those encounters was inflected by the suburban population density and by the extensive network of segregated pedestrian footpaths of the new town, which were relatively safe and easy for AIs to navigate (CMK Town Council, 2018). The impact of physical context on human-robot interfacing may be best understood by contrast with studies regarding the use of delivery robots in more dense urban centres. 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 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 (Salvini et al., 2021). Classical mapping and navigation algorithms are considered insufficient for safe operation of robots around pedestrians in dense urban settings, which are likely to require consideration of the sometimes random and sometimes linear flows of pedestrians (Du et al., 2019)(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 (Bera et al, 2017; Woo et al., 2020).

The current generation of urban robots has a limited ability to interface with humans when faced with an unscripted encounter – they can adjust their routes around them as if they were obstacles to be avoided but they cannot engage with them in a more meaningful way as they lack understanding of their psychology or the conventions of human space. However, this does not prevent the formation of impactful (even if one-sided) affective interfaces. 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 can be seen as non-threatening, helpful, friendly and endearing even as they occasionally struggled to complete their assigned task (Sumartojo et al., 2021). As the wide footpaths 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 of street-goers reacting positively to them (Jennings & Figliozzi, 2019). 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 (Hamilton, 2021).

Having briefly discussed how humans and robots can interface through computer and mobile phone applications and also through social or parasocial interfaces, physical interfaces also merit brief discussion. Urban robots are also material artefacts and in the case of grocery deliveries users are required to physically interface with them – that is, to unlock the hatch, reach in, unload the robot and close the hatch. Although such a basic physical interface may seem simple and self-explanatory it can also constitute a barrier for some potential users, as may also the case regarding the digital interfaces. Such exclusions, which became more impactful in the context of the pandemic, will be further discussed later in this chapter.

Learning machines and distributed cognition

AI is strongly associated with machine learning. Deployments of urban AI have predominantly followed experimental logics designed to facilitate learning by the robots themselves, which are increasingly driven by neural networks as necessary for engaging with an uncertain environment that cannot be possibly apprehended in formal rules (Stilgoe, 2018). Cognition is the defining characteristic of AI. Specifically, to be considered as such an artificial intelligence must have the ability to learn, acquire information from its environment, make sense of it, and make decisions under uncertain, unpredictable conditions without human supervision (Yigitcanlar & Cugurullo, 2020). Robots such as the Starship fleet are intelligent enough to make decisions and act without supervision in complex urban environments, but only within very specific domains - determining and executing complex routes and optimising the operations of a robot fleet. As such, when the robots are considered in isolation, they can be classified as possessing ‘artificial narrow intelligence’, the AI level that current technologies can provide (ibid). However, the case study suggests that the social-robotic symbiosis has learning capabilities that greatly exceed those of robots alone. Organisations and collectives also learn, including collectives that include human and non-human, artificially intelligent actors. Social and collective learning must therefore be analysed as co-productive of one another (Fourcade & Johns, 2020; Hasse, 2019).

In a narrow sense, autonomous operation of the Starship robots relies on machine learning through neural networks (Pärnamaa, 2018) which allows 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). Computations that need a rapid response are performed on-board, while those that are less time-sensitive are offloaded to servers in the cloud (Kosonen, 2020). Starship's neural networks learn from data collected in the course of everyday operations as each individual robot encounters and processes new situations. However, the learning process becomes collective as robots pool their 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 (Kosonen, 2020). The presence of a collective AI became crucial during the pandemic as, supported by rapid social learning, it facilitated a rapid reconfiguration to be discussed in the following section. 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.

(Re) configurations

The notion of cyborg urbanism draws attention to the intensification of dependence and coevolution between urban societies and urban technological networks. Deployments of urban robots are predominantly driven by experimental logics specifically designed to investigate alternate sociotechnical futures and disrupt sociotechnical configurations (While et al., 2021). The introduction of robots in MK was explicitly experimental, as is often the case in cities where robots are deployed to prefigure alternate sociotechnical futures and disrupt sociotechnical configurations (ibid). When Starship delivery services were first envisioned, the legal status of unaccompanied autonomous robots in urban environments was unclear owing to a lack of regulations and legal precedent (Ackerman, 2015). 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 (Pinsent Masons, 2021), leading to the deployment of Starship robots in MK in 2018. Local authorities in MK were 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 (reinforcing the position of MK as a smart test-bed and its connection to technology industries and capitals) and they also had transformative aspirations – they considered that the introduction of robots would support their environmental goals by reducing car dependency, with users ordering robot deliveries instead of driving to the shops (Milton Keynes Council, 2018).

The various aspirations driving the acceptance of urban robots by local authorities in MK illustrate how such experiments can potentially transform urban life but may also sustain existing configurations and reaffirm the dominance of existing interests deliberately or accidentally (Dowling, 2020). Although urban robots can transform the city, they can also be used to give it continuity by repairing or optimising urban activities (Yeo & Lin, 2020; Macrorie et al., 2021). That is illustrated by the role played by Starship robots during the global pandemic, when they functioned as automated infrastructure. Such deployments of urban AI are often associated with a logic that seeks to minimize disruption, increase efficiency, and optimize network capacity. The cybernetic nature of such developments is applied to manage urban flows and processes with minimal human agency (Macrorie et al., 2021).

Even before the pandemic, the introduction of robots sought to reconfigure the links between grocery deliveries, transport and human labour, although the pandemic altered the rationale for the reconfiguration. Before the pandemic the rationale was mainly economic. In terms of speed and carbon footprint, the robots' performance is comparable to that of bicycle couriers but they are expected to cost 10 to 15 times less than other last-mile delivery alternatives when deployed at scale (Ackerman, 2015; London Assembly , 2017). Covid made it so that it was desirable to reduce the role of humans not only for economic reasons but also to avoid face to face contact and reduce the risk of contagion.

Company executives state that the number of orders doubled virtually overnight and the fleet was working non-stop 14 hours a day (Shirbon, 2020) but the service remained able to offer same-day deliveries. 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. The 300% increase in capacity achieved during the first weeks of the lockdown in MK demonstrated that the mix of cybernetic and organic characteristics of the robotic autonomous system can facilitate very rapid reconfigurations. Such a rapid transformation would have been difficult or downright unfeasible for car-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 Starship programme in MK was partially attributable to a fortuitous contingency: Outside of MK, Starship robots were predominantly deployed in campus setting that acted as innovation precincts (Dowling, 2020). As universities closed due to the pandemic, robots became available and could be redeployed to MK. However, as the preceding section revealed, the characteristics of urban AI also played a crucial role in making such rapid reconfigurations possible.

3.3 Outcomes – towards the cyborg city

The preceding sections of the case study interrogate the processes, relations and affects through which a robotic system transformed the urban fabric and was transformed by it. Here we investigate the effects (some temporary, some lasting and some unevenly distributed) that the robotic system had as it contributed to the response to the crisis, as well as the effect that the moment of crisis had on the system. As discussed in the introduction to this case study, factors including supply-chain disruptions, panic buying and the increased risk of contagion associated with grocery shopping during the early days of the pandemic greatly increased the demand for robot deliveries in MK. Consequently, the size of the Starship fleet increased through accelerated (re)configuration and learning processes. Before the crisis began, the Starship fleet in MK had 30 robots and had completed 100,000 deliveries in two years of operation. Six months into the pandemic, the fleet was expanded to 100 robots, and one year into the pandemic 1.5 million deliveries had been completed. The expansion reflected framing of robot deliveries as one of the most reliable ways to protect vulnerable populations and enable social distancing during the COVID-19 pandemic (Starship, 2021). The disruption to online grocery deliveries caused by Covid was particularly problematic for vulnerable individuals including older adults, people with underlying health conditions or those less able to move (Hobbs, 2020), who often rely on home deliveries to remain independent (Jesus et al., 2021). Individuals with disabilities and those in high-risk groups were often unable to secure deliveries despite attempts by supermarkets to allocate additional priority slots (Gleason et al., 2020). Consequently, 55% of disabled adults surveyed by the Office for National Statistics reported difficulties accessing groceries, medication and essentials and approximately 8% of the adults in the UK advised to self-isolate experience food insecurity directly attributable to isolation (Loopstra, 2020; Office for National Statistics, 2020) - 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 it (Eskytė et al., 2020).

Even before the crisis, local authorities in MK had anticipated that robots would be useful for providing deliveries to households that suffered from reduced personal mobility (Milton Keynes Council, 2018), a view supported by commercial partners (Co-op, 2020), investors (Lienert & Lee, 2020) and disability support groups (Disability Horizons, 2020). However, the benefits provided by the robots were not evenly distributed. The emergency exacerbated and gave relief to the potential role of urban robots in either challenging or inadvertently reinforcing inequality This suggests that the emerging cyborg city is at risk of reproducing or reinforcing various forms of inequality, fragmentation, splintering and injustice as noted by urbanists and geographers who have investigated smart and cybernetic cities (e.g., Odendaal, 2021; Clark, 2020; Martin et al., 2018; Krivý, 2018). 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 or marginalised groups, such as those subsisting on a disability allowance, would not be able to pay the 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 (Gleason et al., 2020; Eskytė et al., 2020). The robots are also unsuitable for some users with physical and mobility impairments. For instance, wheelchair users found it difficult to reach and unload the robot.

The limitations discussed above indicate that robots are not suitable as sole responders to crisis events. In addition to their limitations and to the inequalities that their use may introduce, artificially intelligent robots are likely to introduce new vulnerabilities. Urban robots, like other urban systems that rely on networked computation, are subject to malfunction as well as to forms of vandalism, disruption and criminal exploitation that risk making city infrastructures insecure and brittle (Kitchin and Doge, 2019). However, even if the robots could not single-handedly address the crisis, they usefully complemented MK's response to it and increased its ability to cope. Resourceful communities can better respond to disaster events as they have more tools to come with solutions (Zona et al., 2020; MacKinnon and Derickson, 2013), and in the case of MK a fleet of intelligent robots became a valuable resource with distinct benefits and limitations best understood in the context of a multi-faceted response. 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. 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. Community and volunteer organisations were also largely caught by surprise by the rapidly changing situation. Interviews of MK-based volunteers confirms that some organisations were able to respond in a matter of days but for others it was a matter of 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 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. 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 rely on the autonomous robot delivery system.

It must be noted that the rapid growth of the robot fleet was sparked by the crisis but outlasted it. The increased demand for on-demand grocery deliveries persisted after the end of the crisis, with the company is planning to expand the total fleet across the UK to 500 robots across seven towns and cities by the end of 2022. Although some users declared that they tried the robots simply attracted by the novelty of the service and many others first tried the robot in the context of the crisis, in the end the service became habitual for a number of users who appreciated the convenience. Here, robots begin to demonstrate transformative potential by eroding car dependency in the city (a fact the company advertised during the fuel shortages of 2021). The company estimates that approximately 70% of its deliveries replace a car journey, so by the end oof 2021 robots in MK had replaced approximately 280,000 journeys and avoided emissions equivalent to 500,000 miles.

4- Discussion

<Figure 2 here>

< **Caption to read: Figure 2 - Starship robots have been tested in challenging weather conditions including rain, snow and ice. Source: Author's original.** >

In this chapter we examine the renewed intensity of robot-human interactions in unpredictable urban concepts through the lens of cyborg urbanism. To this end, we present a case study tracing the contingent (re)configurations of robots, humans, institutions and infrastructures in the context of the Covid pandemic and the ensuing lockdown. Thus, the case study draws attention to two salient aspects of the cyborg. First, the case study reveals that autonomous robots became part of urban configurations better able to adapt and respond to unpredictable and potentially hostile conditions. Second, it highlights how such benefits were not attributable to the robots alone but emerged from the symbiosis between humans and robots. The presence of AI-driven robots was not in itself sufficient to produce such urban cyborg configurations. Just as Frankenstein's monster was brought to life by a lightning bolt, the cyborg appears to gain renewed intensity when times of crisis provide a galvanising spark. Here the emergence of the cyborg city is seen not as a linear trajectory but as a non-linear fluctuation of intensities, a folded or crumpled time, with crises linking the present to the times of war and uncertainty in which cyborgs were originally conceived. Artificial intelligence is progressing lineally or perhaps even exponentially but even the relatively narrow AI powering the Starship robots proved to be enough to give rise to cyborg configurations as the crisis encouraged a symbiosis and intensified the encounters between humans and robots and the shared processes of learning, with the disruption to everyday life making reconfiguration necessary and spurring the intensities required to transition to new ways of living with AI in the city.

Although the case study discussed in this chapter is centred on the response to the Covid-19 pandemic, other urban crises may be expected and robots can be expected to play ever-increasing roles in crisis responses (Yigitcanlar et al., 2020). For instance, 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 (Roe, 2020). Starship robots were able to continue in operation during the major weather disruption caused by Storm Emma in 2018 (Pärnamaa, 2018; Morris et al., 2018) and were also advertised as a petrol-saving alternative to a shopping trip in response to the petrol shortages of 2021.

As robots were collectively learning how to become urban, an unexpected shock tested their ability to apply what they had learned to deal with a suddenly changed world. The resulting urban (re)configuration can be seen as confirmation of a familiar pattern, as the relationship between disruption, shock and innovation is well known in the literature (e.g., Van de Ven et al., 2020; Bessant et al., 2015). However, what is unexpected is the speed of the response – Robots adapted to the crisis in a matter of days or even hours, drawing attention to the cybernetic principles of real-time adaption to unpredictable environments (Tomas, 1995; Wiener, 1948). Here, real-time adaption depended on the mutual attunement of artificial intelligences and urban processes. Robots were able to support the city during a crisis because they were already embedded in its infrastructures, institutions and practices. 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 could readily repair some urban flows because it was already embedded in them and trained to self-organise and maintain efficient operations in changing circumstances. Also, importantly, local authorities, users and other members of the extended constellations 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.

However, as the case study reveals, the deployment of urban robots has transformative potentials that go well beyond the cybernetic optimisation and maintenance of urban flows in times of crisis. Emergent configurations and contingent encounters of humans, robots, spaces, infrastructures and institutions (re)configure the city as "new technologies become enrolled into complex, contingent and subtle blendings of human actors and technical artifacts" (Graham, 1998:167, quoted in Yeo & Lin, 2020). When the collective intelligence of the Starship "hive mind" and the institutions around it had to reframe their knowledges to cope with a world that changed seemingly overnight, the disruption proved to be revelatory of broader issues about how robots learn to be in cities and about the boundaries and interfaces between cybernetic and human networks in the city, thus bringing into sharp relief the easily neglected processes through which urban robotics sustains some aspects of urban life and challenges others.

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