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Autonomous Mobile Robots: Opportunities and challenges

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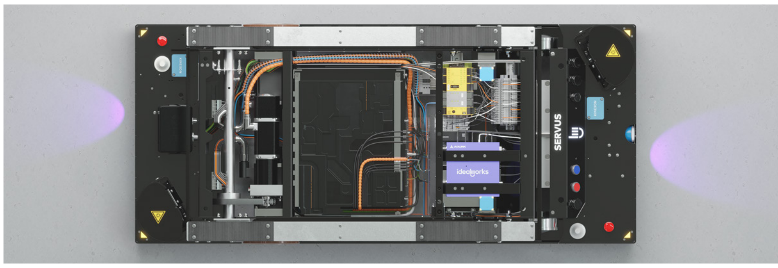
This paper aims to provide a brief insight into the complexities emerging as a result of the shift into Industry 4.0, which is characterised in part by flexible robotic automation equipment and intelligent decision-making software platforms. This paper will centre around the topic of Autonomous Guided Vehicles (AVGs) with a focus on a subset of this technology; Autonomous Mobile Robots (AMRs). As this topic has been covered in detail in other works, this paper will focus on an emerging research area that explores the dynamics between people and these new technologies, exploring the opportunities they offer and the challenges they present. This paper will draw on existing work within the field and interviews with individuals working within this space.

AVGs were first introduced into factories in the early 1950s for industrial intralogistics and material handling processes (Oyekanlu et al., 2020; Vishwakarma, 2019). These automated logistics systems obeyed simple instructions and utilised extensive infrastructure to navigate through factory environments along fixed routes. “Traditional” AVG technologies relied on wires, tracks or magnets embedded in the ground, and simple sensors in order to avoid collisions (Karabegović et al., 2015; Vishwakarma, 2019). As computational technology has become smaller, cheaper, and lighter, AMRs have arisen as a more sophisticated subset of AVG technologies (Karabegović et al., 2015; Siegwart et al., 2004).

Figure 1. Automatic warehouse [Photo] by Senoner, 2020 (https://unsplash.com/photos/yqu6tJkSQ_k)

AMRs present a shift to greater autonomy, with robots capable of adapting to environmental changes through internal mechanisms that guide their movement and allow for adaptive path navigation in real-time (Karabegović et al., 2015). This level of autonomy is achieved by integrating onboard sensors and more powerful processors that are used to establish an internal understanding or mapping of the operational environment (Siegwart et al., 2004). These technological advances mean AMRs can navigate dynamically, planning their movement quickly and efficiently, with greater capability to recognise, react and adapt to obstacles such as people, cars, and forklifts (Karabegović et al., 2015; Siegwart et al., 2004). Furthermore, it means they can be implemented into factory spaces with far fewer infrastructure requirements reducing costs while providing environmentally adaptive capabilities (Karabegović et al., 2015; Oyekanlu et al., 2020).



Top view internals [Digital render] by idealworks, 2021. Copyright 2021 idealworks. Reprinted with permission.

The higher capabilities provided by AMRs allow them to fulfil new roles within factory spaces with greater autonomy meaning they can be assigned jobs, tasks, or missions that they can carry out independent of human involvement (Karabegović et al., 2015; Oyekanlu et al., 2020). Furthermore, the improved sensor technologies and collision detection systems allow them to operate within shared spaces with humans; this represents a level of human-robot collaboration (HRC) not previously possible (Cheng et al., 2018; Siegwart et al., 2004).

While this flexibility means AMRs can be programmed to meet multiple use case scenarios within factories that traditional AVG systems cannot, it also presents numerous challenges. As the systems used to control these technologies become more complex, so are the

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Figure 3. Lidar Closeup [Digital render] by idealworks, 2021. © 2021 idealworks. Reprinted with permission.

difficulties that designers, engineers and roboticists face in developing, managing and supporting the implementation of these technologies ("Human Centred Factories: White Paper," 2019; Oyekanlu et al., 2020; Sauppé & Mutlu, 2015; Villani et al., 2018).
As opposed to fixed tracks, real-time pathway planning and navigation requires a far greater understanding of the dynamics of human behaviour to ensure safety, efficiency and high levels of collaboration (Cheng et al., 2018, p. 1981). Operating autonomously within shared spaces also introduces challenges that are more social in nature than engineering-focused, as these systems are expected to conform to human social and behavioural norms (Mead & Matarić, 2017; Mutlu & Forlizzi, 2008; Reddy et al., 2020; Villani et al., 2018). Compared to older AVGs, where the movements and behaviours were reasonably predictable, the freedom of movement presented by AMRs introduce significant unpredictability. The dynamic nature of these technologies requires greater levels of information and feedback from these robots to workers. In order for them to determine the intention of movement and allow the robots to engage in socially aware pathway planning, such as "giving right of way" or "overtaking" and other proxemic behaviours which are essential to ensuring the successful integration of these systems (Mead & Matarić, 2017; Mutlu & Forlizzi, 2008; Rios-Martinez et al., 2015; Strassmair et al., 2014; Truong & Ngo, 2017).
Failure to address these challenges can lead to detrimental workplace practices and behaviours (Mutlu & Forlizzi, 2008). The evidence of this can be seen within the phenomenon of "abusing robots" or "violence against robots". This phenomenon is characterised by human-robot interactions in which people will intentionally engage in destructive acts towards robots within public spaces and workplaces (Bartneck & Keijsers, 2020; Johnson & Verdicchio, 2018; Mutlu & Forlizzi, 2008). Mutlu & Forlizzi (2008), provide an interesting case study analysis of this in a workplace in their 2008 paper looking at the impact of logistics robots on organisational processes and structures. They found that the success of AVG implementation was closely correlated to how the robots fit within the departments social and workplace dynamics. For example, workers from specific departments complained that the robots did not follow social norms such as "right of way" behaviour and, on several occasions, ran into people as the robot tried to navigate high traffic environments. Workers also reported kicking or otherwise intentionally damaging the robot as a result of these negative interactions. While this paper is several years old now, and there has been significant development within this field, these challenges are still present within more modern systems (Oyekanlu et al., 2020). Furthermore, these types of events can lead to distrust of these systems and promote adversarial interactions between humans and robots (Mutlu & Forlizzi, 2008; Nam & Lyons, 2020).

Figure 4. Research Notes [Photo] by BMW + QUT Design Academy, 2021. © 2021 Jordan Domjahn. Reprinted with permission.

The underlying question is how we rise to and overcome these challenges to ensure that AMR systems can be implemented effectively and bring about positive outcomes for both workers and companies. The "Human Centred Factories: White Paper" (2019), argues this will require a greater human-centred perspective in which the needs, abilities, expectations and limitations of humans are considered and successfully addressed (Truong & Ngo, 2017; Villani et al., 2018). An acknowledgment of these needs is highlighted in an emerging field of research looking at how to achieve greater levels of HRC through affective based communication systems that can detect human emotion and communicate with robot operators and general factory workers using parallel forms of information encoding (Elprama et al., 2016; "Human Centred Factories: White Paper," 2019;

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Kumar, 2019; Landi et al., 2018; Rahman, 2019; Rios-Martinez et al., 2015; Strassmair et al., 2014; Vinciarelli et al., 2009). The successful implementation of these research findings, methods and frameworks will likely require close collaboration between researchers and industry. The question then becomes how to establish meaningful and sustainable relationships that address real-world industry and user needs while maintaining a human-centred perspective.

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