AI Camp project
Tackling Climate Change with Robot Learning

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Contents

Abstract

The integration of Artificial Intelligence (AI) and robotics into climate action represents a transformative approach to addressing the global challenge of climate change. This paper explores the innovative applications of AI and robotics across various sectors such as environmental monitoring, agriculture, waste management, and transportation. By enhancing the precision and efficiency of data collection and analysis, these technologies offer potential solutions to reduce greenhouse gas emissions, optimize resource use, and improve sustainability efforts. This report discusses the challenges and barriers to integrating these technologies, including technological limitations, high costs, and the need for robust governance frameworks. It also highlights the importance of interdisciplinary collaboration and public engagement to ensure that the integration of AI and robotics aligns with ecological and social goals. The future directions of this burgeoning field emphasize scaling and affordability of technological solutions, advancing regulatory frameworks, and fostering international cooperation to fully harness the capabilities of AI and robotics in mitigating climate change impacts. This paper represents a comprehensive overview of the current landscape and the future of AI and robotics in environmental sustainability efforts.

1 Introduction

Climate change remains one of the most significant challenges of our time, demanding innovative solutions and interdisciplinary approaches. As the effects of rising global temperatures become increasingly apparent, the urgency for effective and scalable solutions grows [34]. One of the promising frontiers in this battle is the integration of advanced technologies such as robotics and machine learning. The concept of utilizing robot learning to tackle climate change involves leveraging autonomous systems capable of learning and adapting to complex environmental tasks, thereby, potentially revolutionizing our approach to environmental management and sustainability.

1.1 Need for Innovative Solutions in Climate Action

The current strategies to mitigate climate change are multifaceted, involving renewable energy adoption, deforestation controls, carbon sequestration, and emissions reductions. However, these efforts often encounter limitations due to human resource constraints, accessibility issues, and the sheer scale of monitoring and enforcement required. Moreover, many of these strategies require continuous and extensive data collection and analysis, tasks that can be enhanced significantly with automation and advanced data processing technologies [36].
Robot learning is equipped with different learning algorithms, that help improve the performance continuously. This capacity of working requires monitoring the climate changes, and challenges in unpredictable ecosystems that are impacted by climate change.

1.2 Robot Learning: Bridging Technology and Ecology

Robot learning is a subset of artificial intelligence that relies on machine learning models that learn from their surroundings[30]. With sensor integration, robots can perform complex tasks that are sometimes difficult for humans to perform. For instance, monitoring forest health, and waste management in urban environments, or restoring coral reefs.
Robots can collect data to a large extent and with great precision, which is unachievable for humans. For example, drones can cover a large area, identifying any unusual pattern in a shorter time. Underwater robots are helpful in mapping and analyzing coral reefs over large areas to monitor pollution effects. This data can inform conservation strategies, enforce regulations, and optimize resource management.

1.3 Potential Applications and Impact

Robot learning plays a very critical role in tackling climate change and perform better across several domains:

1. Environmental Monitoring and Conservation:
Robots are helpful in the conservation of wildlife populations. Robots track changes in the ecosystem and are even helpful in restoring their habitat. For example, robots planting trees and dispersing seeds in areas where the ratio of plants is very low. This phenomenon will lead to reforestation from deforestation and require minimal human intervention and effort [20].

2. Pollution Control and Waste Management:
Robots can automatically identify, clean/pick, and manage waste, leading to a significant reduction of waste in the environment. Robots with learning algorithms can optimize routes for collection and processing, enhancing efficiency and reducing emissions associated with waste management [15].

3. Energy Efficiency:
Robots are playing a significant role in optimizing energy usage in different industrial sectors, smart grids, and residential sectors [14]. Through continuous learning and adjustment, these systems can significantly reduce wastage and improve the energy efficiency of various processes.

While the potential of robot learning in environmental applications is vast, several challenges need addressing. These include technological limitations, high initial costs, ethical concerns regarding automation, and the need for robust, transparent frameworks to ensure that the deployment of such technologies aligns with public interest and ecological sensitivity. Moreover, integrating robot learning into environmental strategies requires interdisciplinary collaboration [22]. Experts in robotics, climate science, and ecology must work together to design systems that are not only technologically advanced but also ecologically sound and socially responsible.

2 Applications of AI and Robotics in Climate Change

Artificial intelligence and robotics are playing a pivotal role in addressing climate change, and providing creative solutions to significant environmental issues. By leveraging cutting-edge technologies, these innovations enhance efficiency, cut costs, and reduce environmental impacts, paving the way for a more sustainable future. These technologies are revolutionizing various industries such as transportation, agriculture, and waste management, showcasing their potential to build a more resilient and adaptable society.

2.1 Self driving cars

The automotive sector is an ever expanding industry, producing 94 million vehicles in 2023, with an increase of production by 10% since 2022 [25]. The vehicles on the road are responsible for up to 27% of greenhouse gas emissions in the USA in 2010 as stated by the United Nations Framework on Climate Change Convention[33]. While in the EU, studies show that the automotive industry has contributed up to 20.8% of the continent's greenhouse gas emissions [3]. The greenhouse gasses, produced by vehicles mostly consist of carbon dioxide (CO2), methane (CH4) and nitrous oxide(N2O). These emitted gasses are the main contributor to the greenhouse gas effect, which acts as an artificial heat trapping layer in the earth's atmosphere leading to an increase in the globe's temperature. The greenhouse effect is a natural processes that has existed before humanity began to burn fossil fuels on an industrial scale. It is part of the natural processes that keeps our planet habitable, but it has a delicate balance [37]. A balance that has been disturbed by humanity's relatively recent industrial activity. With the growing effects and concerns of global warming come multiple potential solutions to the problem of greenhouse gas emissions, one of which being Autonomous Vehicles, also know as self-driving cars or driverless cars. These vehicles are capable of operating themselves without a driver controlling the steering, acceleration, breaking and navigation. They poses varying levels of autonomy depending on the technology used and their manufacturer. The global number of self-driving cars in 2019 was 31 million and that number is expected to surpass 54 million in 2024 [24]. Driver-less cars are equipped with an array of tools such as artificial intelligence that enable the vehicle to manoeuvre with little to no input from the driver. The presence of these vehicles on the road has an impact on traffic safety, the frequency and behaviour of congestions and notably for this paper, an effect on fuel use, travel frequency and energy use. The increase in efficiency of which could lead to a notable change in greenhouse emissions. There are multiple factors that determine the impact of Autonomous Vehicles on emissions, from the technology used, flue type and age to their penetration among non-autonomous vehicles on the streets and the use-case of their users. The further introduction of self-driving cars may contribute to an improvement of traffic flow, the efficiency of driving and routing, less hunting for parking, ride-sharing, etc. All of which mean less cars on the road spending less time driving resulting in less emissions. On the other hand the convenience of drivelers cars might lead to and increase in their use.

2.1.1 Causes of Reduction in GHG Emissions

Often drivers spend time in parking lots and on the street searching for a suitable parking space. This meandering results in not only a decrease of fuel efficiency but also additional congestion of traffic. In addition incorrectly executed parking maneuvers can also contribute to inefficiency and emissions. A solution to this problem is Easy parking, a network consisting of Autonomous vehicles, sensors, mobile applications and guidance systems that communicate with each-other, with the goal of informing Autonomous vehicles of parking locations that are open and close by. Multiple self-driving cars also poses automated parking algorithms which could be more consistent in the execution of parking maneuvers. A study by Brown et al. estimated up to 5% of emissions in an average passenger car is attributed to the search for parking [7]. As a result, fully autonomous vehicles can achieve a reduction of greenhouse emissions by 5-11% from reduced driving in search of a parking space. Eco-driving refers to a driving technique that attempts to improve fuel efficiency. Many driver-less cars are capable of following these techniques or even surpassing them by communicating and coordinating with other autonomous vehicles to optimize traffic flow. According to a traffic simulation model by Matthew Barth and Kanok Boriboonsomsin, a group of cooperating autonomous vehicles intermixed with normal vehicles on a crowded highway could lead to a 10-20% decrees in emissions [6]. Aside from communicating with each other, autonomous vehicles can communicate with the infrastructure around them such as traffic signals at intersections. The information provided by the infrastructure enables autonomous vehicles to minimize stops at intersection, improving fuel economy. This is referred to as Eco Traffic Signal. Self-driving cars can also work together to minimize aerodynamic drag by driving close together. This is referred to as platooning. In this scenario, the cooperating vehicles can communicate and avoid collisions while improving each-other's fuel efficiency. Since a significant amount of the vehicles energy is expended in combating aerodynamic resistance, platooning can have a significant effect on improving fuel efficiency and minimizing gas emissions.

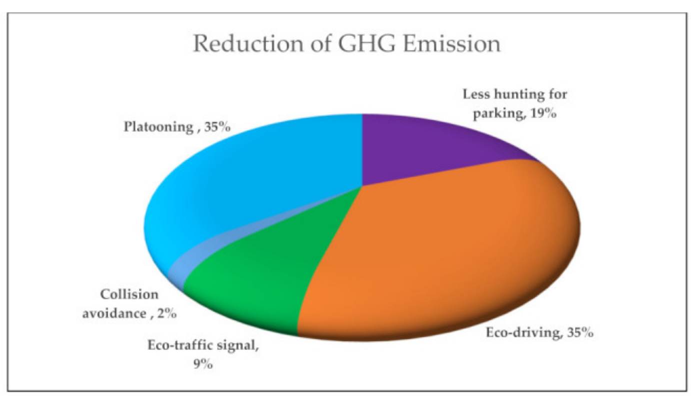

Figure 1: Average contribution of the causes on GHG emission reduction. [19]

2.1.2 Causes of Increase in GHG Emissions

As stated above, the convenience of drivelers cars might also present scenarios in which we could see an increase in emissions. This potential increase is due to an increase in the time and amount of vehicles that are used. Travel with self-driving cars is faster and easier, with less time spent stopping and starting at intersection, safer increase in driving speeds and better fuel efficiency, thus longer and previously avoided trips will now be accessible, leading to an increase of travel. As a result of cheaper and safer travel, people will be more interested in the use of autonomous vehicles leading to a further increase in greenhouse gas emissions. With the use of an activity-based travel model-generated scenarios, potential changes in travel patterns were analyzed, resulting in a 30% increase in roadway capacity along with a 19.6% increase in emissions [8]. The increase in road safety from driver-less cars, due to the autonomous vehicles ability to communicate and cooperate with each other, while also not having to rely on a driver's reaction speed to avoid collusion, could lead to and increase in highway speed limits. This means an increase in fuel consumption not only by driver-less cars, but by conventional vehicles as well. This increase in the speed of which vehicles travel, by itself, could also lead to an increase in emissions, as vehicles traveling at faster speeds, burn more fuel. Using the typical car's speed-fuel consumption relationship, it can be concluded that the potential increase in greenhouse gas emissions on highways could be 20-40%.People, such as the elderly and disabled, would now be able to able to travel without assistance, as autonomous vehicle would prove to be more accessible and easier to use for those groups. Since it is difficult to predict the travel patterns of people who don't usual travel, it is hard to asses the potential increase of travel and subsequent emissions. Still, by enabling formerly non-driving populations to drive, those being non-drivers 19 and older, elderly drivers without a medical condition, and drivers 19 and older with a medical condition, it was estimated that the under-served could increase emissions up to 12% by using fully automated vehicles.

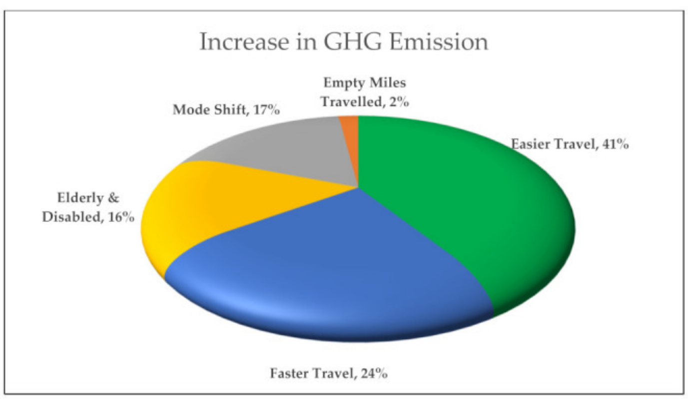

Figure 2: Average contribution of the causes on GHG emission increase.[19]

2.1.3 Penetration of autonomous vehicles

The above stated causes that could effect greenhouse gas emissions all rely on the assumption that there is a notable amount of driver-less cars simultaneously in use. As meany of the features, such as platooning and Eco-driving, that enable the increase in car use and fuel efficiency, are only possible if there are multiple autonomous vehicles on the road that can communicate and cooperate with each other. Other features of self-driving cars that rely on communication between vehicle and infrastructure would also be impacted by the limited spread of these vehicles. After all it is not worth the cost and effort of upgrading existing infrastructure to enable features such as Easy parking and Eco-traffic signal if only a small fraction of all cars on the road would benefit from it. Thus in order for autonomous vehicles to have any notable effect on the greenhouse gas emission of the automotive industry, there needs to be a large presence of driver-less cars among conventional cars. In other words a high amount of autonomous vehicle's Penetration. Multiple studies have been made in an attempt to determine the effect of autonomous vehicles on greenhouse gas emissions at different penetrations. Some of these were made by Stogios et al. ,Olia et al. and James Conlon and Jane Lin [31] [4] [9], the results of which are available in the flowing image.

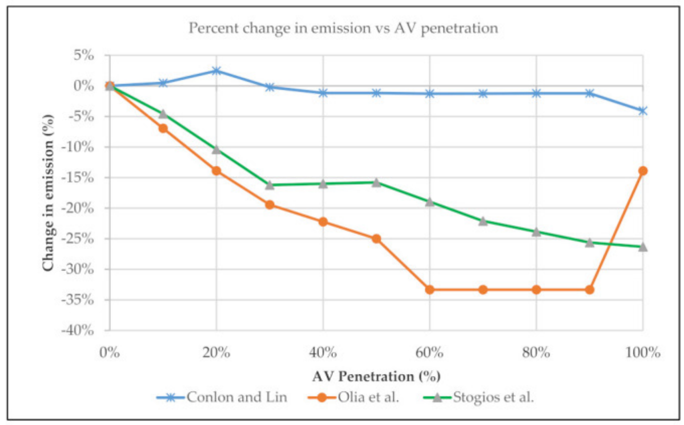

Figure 3: Emission changes by AV penetration. [19]

2.1.4 Conclusion

The effect of autonomous vehicles on greenhouse gas emissions is difficult to determine. The decrees of emission by the many features of self-driving cars is unavoidably negated by the increase of travel speeds and frequency of travel. Thus any possible decrees in emission might be undone by a surge of vehicle miles traveled. It is even possible that autonomous vehicles could increase emissions if they are deployed in less ideal areas that do not support many of the vehicles features, or if the transportation sector continues to be dominated by privately owned vehicles. Further yet the positive environmental effect of self-driving cars could only be achieve at a penetration of 60-80%. To further compound the issue of determining the net effect drivelers cars can have on the environment, the technology is relatively new and there are too few studied on the subject, while many of the existing studies rely on simulations rather than real life cases. To summarize. Autonomous vehicles could potentially have a notable positive effect on the planets environment by lowering greenhouse gas emissions, however this positive effect will not be fully realized at lower autonomous vehicle penetration among conventional cars. Further more said effect could be negated to an unknown extent by an increase in car travel.

2.2 AI and Robotics in agriculture

Agriculture is not one of the main fields that comes to the public speaking when AI and robotics are discussed, probably because it is less appealing to show a drone that flies over a crop field than a humanoid robot doing parkour. Most of the time we underestimate the importance of agriculture in our society structure, it is able to influence all human activities and given its role we should be more concerned with its smooth functioning. This is even more crucial in our time where the consequences of climate change and the increase in food demand can really undermine the sector. The Food and Agriculture Organization predicts a global population of 9.7 billion by 2050, necessitating a staggering 70% increase in agricultural production [12], on the same topic a meta-analysis on Nature [21] gave more cautious predictions with an increase between 35% and 56%. Concurrently climate change can affect crops, livestock, soil and water resources while it can make conditions better or worse for growing crops in different regions demanding for meticulous planning and adaptability. The effects of climate change such as drought and changes in rainfall patterns are already impacting agriculture, a NASA study [23] found that the production of corn and wheat will be affected as early as 2030 where the first see a decline of 24% and the latter a potential growth of 17%. These projections were derived from two sets of models that take also into account the possible shifts in the regions where these crops may be cultivated (Figure 4). Taking the U.S. example although there may be some local positive impact on the yields of some crops the national aggregate returns is expected to decline with the increasing severity of the climate change scenario. As an additional real case on the possible impact of climate change the 2012 U.S. drought that affected livestock, wheat, corn, and soybean production resulted into a $14.5 billion loss for the federal crop insurance program [26]. Given these issues, the common employment of suitable technologies and well structured policies are necessary.

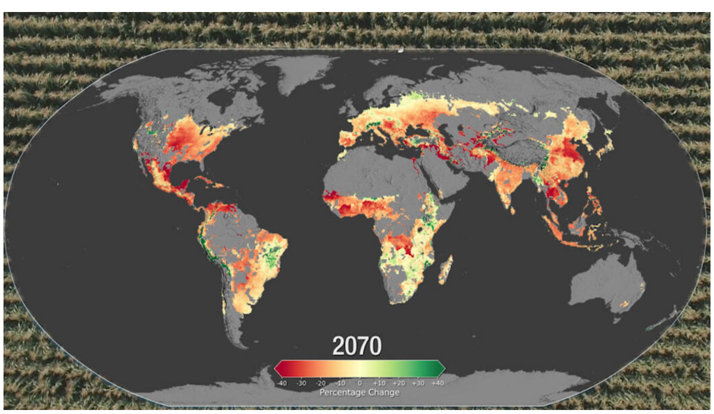

Figure 4: Map of the world showing in red where decreases in corn yields are projected to occur in 2071 4

The advent of Robotics and Artificial Intelligence (AI) has revolutionized numerous sectors, and agriculture is no exception. The integration of these advanced technologies in agriculture aims to increase efficiency, reduce human labour, and enhance production and management systems. Starting from the academic relevance of these topics Oliveira, R.C.d. and Silva, R.D.d.S.e. [28] performed a systemic review that among other objectives showed that publications accounting for AI and agriculture have a steady increase from 2017 to 2022 where the number of publications tripled in the last three years. The same trend can be observed considering a longer timespan ranging from the global food price crisis in 2007-2008 to 2018 [21]. From the economic point of view, agriculture account for approximately 4% of the world's GDP and in some least developed countries it's contribution can exceed 30%, some examples are Chad (54%), Ethiopia (37%) and Liberia (37%) [10] [5]. Recent advancements in AI and robotics technologies have opened up new opportunities for the agricultural industry. With AI-powered systems and robots, farmers can optimize crop production, monitor plant health, and automate labour-intensive tasks. This not only improves efficiency but also reduces costs and minimizes environmental impact. According to a report by the World Economic Forum [13] considering the economy of India only, capitalizing on the value of emerging technologies such as artificial intelligence (AI), drones, and the Internet of Things (IoT) has the potential to impact productivity and efficiency at all stages of the agricultural value chain. For instance, data-driven agriculture, through enhancing 15 datasets including soil health records, crop yields, weather, remote sensing, warehousing, land records, agriculture markets, and pest images, could realize a $65 billion opportunity. Moreover, automation in agriculture can help farmers reduce costs, improve efficiency, reduce their environmental impact, and address labour shortages. In the following subsection we will focus on some real applications of robotics and AI, doing a brief overview of the technology involved and, where available, the quantitative impact on farmers and on the environment.

2.2.1 Harvesting data

The advent of smart agriculture, powered by a plethora of digital innovations, has transformed farms into highly efficient, interconnected ecosystems. At the heart of this agricultural revolution lies the omnipresent force of data. From sensors monitoring soil moisture levels to drones mapping crop health, the agricultural landscape is increasingly reliant on the insights given by data analytics. This not only make it possible to have a real-time feedback on the farm condition but it also allows long-term analysis that gives an higher degree of adaptability and forecasting capabilities for endogenous or exogenous phenomena. One of the main tools for gathering data in smart farms are unmanned aerial vehicles (UAVs), hereafter called drones. These vehicles have attained a degree of dependability at reasonable prices, rendering them attractive for commercial uses. Their market is rapidly expanding, in 2023 it's size was $4.5 billion and it is predicted to grow at a CAGR of 31.5% between 2023 and 2028 [18]. One of the main usage for drones is the imagery of farm crop's fields. In the 2000s, satellite imagery served as the primary information source, offering insights into the fields but one notable limitation was its inadequate resolution, infrequent updates, and significant delay between observation and application. Aerial imagery obtained from balloons and aircraft served as additional options for data gathering. Nonetheless, the substantial expense associated with data collection posed a significant challenge. The introduction of drone-based imagery in agriculture marked a significant advancement, providing extensive coverage, immediate access, and mosaic images in a short timeframe, facilitating high-quality decision-making. Professor Wei Guo and his team developed [35] a specialized software pipeline to predict the optimal broccoli harvest time in terms of economic return by using drone-based digital measurement. A low-cost drone with a simple RGB camera was used to acquire field images that were later used in two deep learning model to detect the broccoli position and to segment the plant's heads. The results of these models were then used to predict the optimal harvest time based on the market price. They used a Yolo v5 model for the seedling position detection which was needed for the later segmentation stage with a BiSeNet v2 model, the segmented results were then transformed in centimeters to predict the broccoli head size through a simple non-linear regression model. The head size is needed to discriminate the category of each individual and consequently its sell price. Their results showed that even a shift of one day in harvest from the optimal date could lead to considerable income loss (3.7% to 20.4% reduction). Of course drones can mount several different sensors such as LIDAR, hyperspectral and thermal to accomplish multiple tasks. These are commonly used to compute a variety of quantitative indicators like the normalized difference vegetation index (NDVI) which use near infrared measurement to calculate the density of green leaves in an area. This measure can be used by farmers to identify the field where pesticides should be sprayed. Marin et al. [17] proposed a framework to detect coffee leaf rust (CLR) using 63 vegetation indices extracted from UAV imagery mainly using Red Edge and Near Infrared measures. With a Logistic Model Tree (LMT) they managed to obtain F-measures of 0.915 and 0.875 for early and later stages of CLR, this data can be used by farmers to identify suitable precision agriculture strategies. The map of the predicted coffee leaf rust is depicted in Figure 5, there can be 4 different classes of rust that the model needs to distinguish in the classification.

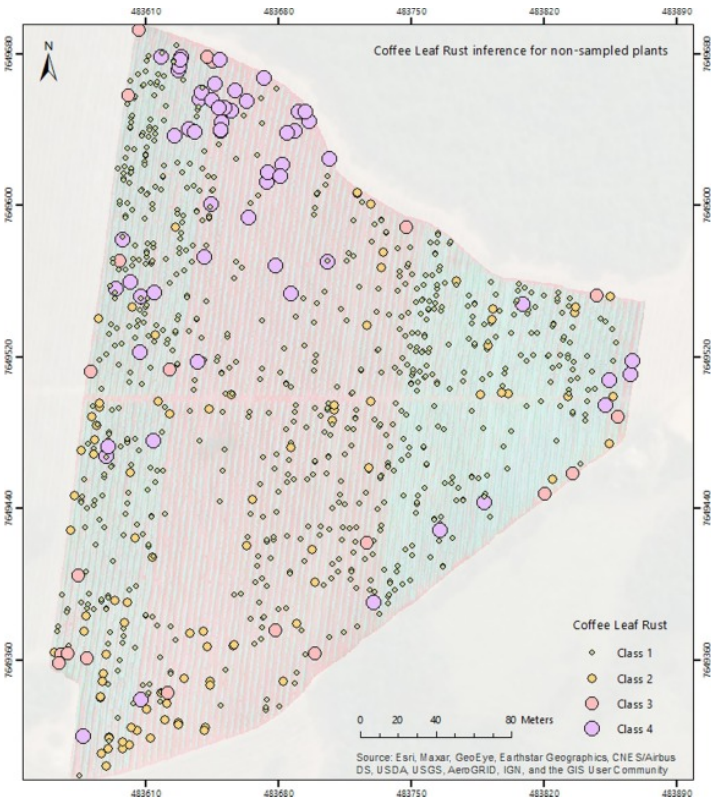

Figure 5: Predicted map of CLR [17]

2.2.2 Robots in the fields

Implementing robotic solutions for crop monitoring and harvesting offers substantial advantages to production profits. It facilitates quicker and smoother automated harvest processes while enhancing crop quality and yield. Consequently, the integration of robotic technologies in agriculture is gathering heightened attention and research efforts over recent decades. This aligns with the broader trend in agriculture called precision agriculture or agriculture with reduced carbon footprint. Agricultural robots must meet a fundamental criterion: the ability to execute diverse field tasks with precision and efficiency, often necessitating unique designs in structures or mechanisms. Nevertheless, despite this diversity, most field operations share a common set of essential functions: autonomous navigation within the field, intelligent decision-making for task execution, and automatic implementation of operations. Nowadays the trend is to develop robots for specific tasks with the necessity to make suitable design choices for the mechanical part and for the software implementation, the global agricultural robots market size was estimated at $11.57 billion in 2022 and is expected to grow at a CAGR of 20.6% from 2023 to 2030 [27]. Robots can be employed in almost every aspect of a farm, from the harvesting of products to their monitoring which may include stripping away the weeds, watering, spraying pesticides or fertilizer and all the post-harvest tasks such as sorting and packing. To bring some examples, Utstumo et al. [32] designed a three-wheel robot for Drop-On-Demand (DoD) herbicide application in a carrot crop. DoD spraying is a technique to detect weeds within the plant row and selectively shoot droplets of herbicide without affecting the crop and the soil. The robot is equipped with a camera system that while navigating can segment and classify the captured image to produce a spray map which is then used by the spray controller to precisely apply the herbicide droplets on the weeds. By performing an on-field trial they demonstrated that their setup can be effectively employed and they also measured a ten-fold herbicide application reduction with respect to common practice. It is worth to mention that the vision processing pipeline don't use any deep learning techniques but it can however achieve outstanding results. Ruigrok et al. [29] developed a mixture of techniques to deal with the elimination of volunteer potato in a sugar beet field, this is a nice example where different technologies such as deep learning, 5G connectivity and autonomous robots are used together to accomplish the task. The robot utilized a mobile platform to navigate autonomously across the field, capturing images with its onboard image-acquisition system. These images were then transmitted to a processing server located approximately 200 km away via a 5G Wireless Wide Area Network (WWAN) where a weed-detection algorithm using a YOLOv3 detection model analyzed the images. Subsequently, the identified plant locations were relayed back to the robot via the 5G connectivity system to direct the spraying system to apply herbicide precisely where needed. In the field experiment evaluation on average, 96% of the potatoes were correctly sprayed and only 3% of the sugar beets were wrongly hit. Lastly we take into analysis the case of a robotic harvesting system for high-quality tea [16], this problem is particularly challenging because the tea shoots are small and exhibit irregular shapes. Three main tasks are performed by the robot: detection of tea shoots bounding box through a YOLOv3 model, the localization of the plucking point and planning of the plucking sequence solved through genetic algorithm by modelling the problem as a travelling salesman problem. The general structure of the robot and its plucking system can be seen in figure 6. The harvesting success rate of the whole process is 53.91% with a 2.233s average plucking time for a single shoot.

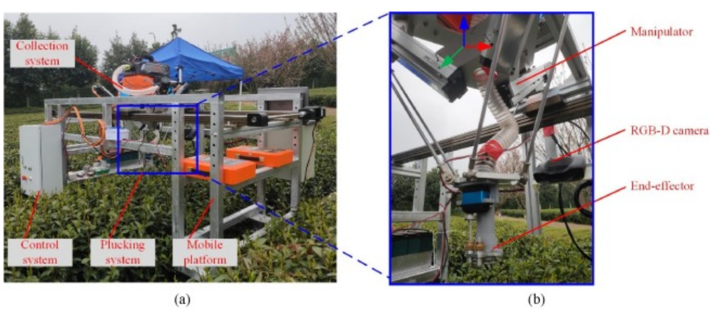

Figure 6: Tea harvesting robot (a) and plucking system (b) 6

2.3 Waste management

Waste management encompasses the collection, transportation, treatment and disposal of waste, together with monitoring and regulation of the waste management process. It handles all waste kinds with the goal of minimising the negative impacts on the environment and public health. Depending on the type of waste—solid, liquid, or gas—different techniques are used to manage it. These techniques include the waste hierarchy, which places an emphasis on reducing, reusing and recycling garbage. Sustainable and habitable cities depend on effective waste management, which calls for integrated systems that are socially, economically and environmentally sound.

Figure 7: Waste Management

Despite the use of many recycling technologies, less than 20% of garbage is recycled each year. The remaining 80% is disposed of in open dumps and landfills. This may cause dangerous chemicals from the trash to leak into the ground, the atmosphere, and the soil. The quantity of waste on the world is predicted to increase by an astounding 70% over the next 30 years, which will only make worse the situation. Natural habitats are destroyed when landfills and other disposal sites fill up to capacity. Furthermore, a substantial amount of greenhouse gases are produced during the production of plastic goods. It is essential to increase the proportion of waste that is recycled. The recycling procedure is still costly and time-consuming, though. All facts referenced in this paragraph are from [11].

Robotics developments provide practical methods for better waste management systems. When armed with sensors, AI and machine learning skills, robots can greatly improve recyclables sorting, properly handle toxic waste and optimise garbage collection routes. These technologies have the potential to decrease carbon emissions, reduce human exposure to toxic materials and promote the wider adoption of circular economy concepts in addition to their stated goal of increasing operational efficiencies. Waste management will change as a result of the intended incorporation of robotics, which will make waste processing safer, more effective and less harmful to the environment.

The article [1] addresses the pressing need for sustainable waste management solutions as a result of the COVID-19 pandemic's increasing global waste problem, particularly with regard to plastic, medical and technological waste. In order to overcome these issues, it highlights the need of implementing a circular economy and embracing green technologies.

With improved sorting mechanisms, robotics is transforming trash management by accelerating and accurately classifying products such as paper, metals and plastics. This accuracy raises the value of recyclables and lowers contamination. Additionally, robots promotes effective collection and handling; for example, autonomous cars optimise routes and cut emissions, while robotic arms handle dangerous materials safely.

Robotics advancements have also made it possible to recycle electronic waste using advanced techniques that allow for safe and accurate component extraction as well as exact disassembly. Robotics reduces risks to health in medical waste management by automating the processing of infectious materials. Robotics promotes the circular economy by enabling the transition to sustainable methods that prioritise resource recovery and low environmental impact. Robots with AI and sensors enable crucial compliance and monitoring, guaranteeing that waste management procedures adhere to legal requirements. These integrated robotic solutions promise more improvements in sustainability and are laying the groundwork for a greener economy.

The article [1] presents effective sustainable methods from a range of industries. For instance, by implementing Eco-Industrial Parks and Eco-towns where recycling and resource efficiency are prioritised, Vietnam and Japan have dramatically cut CO2 emissions. Green technology is being advanced in the electronics industry by businesses like Apple and HP that use recycled materials in their products. Additionally, quicker degrading options are provided by the introduction of biodegradable materials like PLA and PHAs, improving environmental sustainability. A global trend towards sustainable waste management practises is demonstrated by initiatives such as the European Battery Alliance's drive to increase battery recycling in Europe. These initiatives are prime examples of how environmentally friendly technologies and materials may be integrated into production processes.

The application of robotics to garbage management improves sustainability and efficiency in a number of ways. Robots optimise material handling and disassembling, enhancing resource recovery and lowering pollution in electronic recycling and Eco-Industrial Parks. Automation improves worker safety and processing accuracy even further in the manufacturing of biodegradable products and battery recycling. These developments not only boost efficiency and productivity but also promote the circular economy by reducing their negative effects on the environment and improving the quality of recycled materials.

We continue with another case study [2](fig 8) and practical use. Waste sorting is being looked into as an automated process by companies like AMP Robotics. The US business uses robotic arms, computer vision and artificial intelligence to physically sort and identify particular recyclable elements from a complex garbage stream of broken, folded, and shredded products. In order to characterise the recycling stream and determine what has to be sorted at different stages of the process, its artificial intelligence platform makes distinctions between various plastic polymers, paper types, metal containers, and multilayered products. High-speed robotic arms sort and retrieve things to recycle or discard using this data as guidance. According to the company, their artificial intelligence system can identify over 70 billion things in real-world scenarios through experience and repetition. These robotic systems have the ability to distinguish and isolate valuable materials from garbage more precisely than human labourers, which could increase the viability of recycling and advance the goal of zero waste.

Figure 8: AMP Robotics

As we look to the future, robotics' potential in waste management will only grow, bringing about radical shifts in the industry. With the advancement of technology, robotic systems' ability to recognise and sort garbage will become more sophisticated, enabling more accurate material separation and a reduction in contamination rates. This development will strengthen the circular economy's tenets by improving the efficiency of recycling procedures and assisting in closing the material usage loop.
Furthermore, waste management techniques will become more responsive and predictive as robotic technologies are increasingly closely incorporated with other cutting-edge systems like the Internet of Things (IoT) and big data analytics. This could result in automated facilities that modify processing techniques based on the content of the incoming waste stream, smart bins that alert users when they are full and dynamic garbage collection routes that are optimized in real-time. These developments will not only boost operational effectiveness but also dramatically reduce waste management's negative environmental effects. In the end, robotics integration may open the door to a world where resources are continuously reused, waste creation is reduced, and sustainability is ingrained in every stage of a product's life cycle. This would be a big step towards the realisation that waste is essentially a resource waiting to be discovered.

3 Conclusion

This report has comprehensively explored the dynamic intersection of AI and robotics with climate action, emphasizing their potential to drive significant improvements in environmental management. As highlighted through various applications, such as autonomous vehicles, smart agriculture, and enhanced waste management, these technologies promise not only to increase efficiency but also to reduce human labor and mitigate environmental impact.
Integration of robots with artificial intelligence (AI) has shown significant impact on climate strategies. It is a challenging task to cover all aspects of climate change because of resource constraints, time limitations, high initial costs, and ethical concerns, etc. However, these challenges cannot stop AI and robotics from achieving their goals of potential benefits. Instead, they generate the need for robust, transparent

governance frameworks and interdisciplinary collaboration to ensure these technologies are used responsibly and effectively.

4 Future Directions

Exploring how AI and robotics can help fight climate change opens up many exciting possibilities for the future. By improving AI's ability to monitor the environment, we can predict changes more accurately and take action before problems get worse. Making AI and robotic technology cheaper is also crucial, especially for developing countries that need these tools the most but can least afford them. Creating clear ethical guidelines and regulations will help ensure that these technologies help protect the environment rather than harm it.

As this field grows, there's a big need for training that crosses different disciplines. Educational programs that mix AI, robotics, and environmental science will be key to preparing the next generation of experts. It's also important to communicate clearly with the public about how AI can help the environment. This will build understanding and support for these initiatives, making it easier to get communities involved.

Looking ahead, we can expand research to include self-driving vehicles in public transportation and develop smart infrastructure that uses energy more efficiently and reduces emissions. Working together on international projects that use AI and robotics to tackle global issues like deforestation and ocean conservation will significantly increase the positive impact of these technologies. By pursuing these comprehensive strategies, we can harness AI and robotics to make significant strides toward a sustainable and resilient global environment, effectively addressing the urgent challenges posed by climate change.

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