IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

THE ROLE OF ROBOTICS TECHNOLOGY FOR A FUTURE SUSTAINABILITY

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ABSTRACT

Emerging technologies, such as robot technology, will impact our future. Just as humans are never content; they're constantly looking for ways to improve, so too are robots. We assess major developments in robots heading into the future and examine potential human and occupational futures. The purpose is on robotic platforms and algorithms for discovering low-computing-power solutions to the problem of identifying and avoiding dynamic agricultural barriers was carried out. The method used Different navigation algorithms are examined in this paper, with the Pure Pursuit Algorithm serving as a benchmark. In order to meet its requirements, the Djedi robot had to navigate the air shafts while causing the pyramid walls as little damage as possible. The goal of this study is to reduce the danger of death and economic loss by real-time monitoring and rescue in hazardous situations such as deep mines and pipe and tube systems. Fast precise tracking control is achievable using MPC and LQR, although these techniques work best in perfectly simulated environments. We can conclude that the relative ease of computing PPA, on the other hand, has made it the preferred approach. Living in this era is the finest thing that could happen, since technological developments are becoming more and more astonishing and because the significance of robotics is becoming more apparent. To these technological advancements, we can now build robots that can do so much more than humans can, making it simpler for us to reach our intermediate and long-term objectives. Successful development of an autonomous navigation system was achieved by zigzagging over all rows of plants. In order to determine the most cost-effective application, many methods were evaluated.

Keywords: Robotics, Environment, Technology, Future, Artificial Intelligence.

INTRODUCTION

The field of engineering known as ‘Robotics’ focuses on all things related to robots, including their inception, design, building, operation, application, and utilization. When we look into it further, we find that robots are described as machines that are run automatically and can carry out a sequence of tasks normally done by humans. By the way, robots may take many forms; some even seem human. Images of car production lines may serve as evidence. "Androids" is the common term for robots that can pass for human. It isn't always the case that robot designers make their inventions seem human so that people feel more at ease around them. Not everyone is comfortable with robots; some find them terrifying, particularly humanoid ones.

Robots find utility in many fields, particularly those that need them to do physically demanding activities or missions that humans would find too risky to attempt. Technologies like AI and robots are causing a societal, economic, and individual upheaval. Robots are versatile in more ways than one. They are consistent and accurate, and they can operate in any setting. Because they can operate in hazardous conditions, robots remove people from harmful professions. Heavy weights, poisonous chemicals, and repeated labour are no match for them. Many accidents have been avoided, and corporations have saved both time and money as a result. Complex procedures, including those for prostate cancer, are performed by medical robots. Robots provide a level of precision that humans just cannot match because of their ability to squeeze into tight spaces. reduced invasive operations and reduced discomfort for the patient after recovery are two potential advantages of robotics in the medical industry. Extreme environments, agriculture, infrastructure monitoring, transportation, social care, and soft robotics are just a few of the many fields that stand to benefit from the development of robotic applications supported by space technology. There may be more innovative ways to deal with this extraordinary crisis brought about by the present epidemic if robotic technology is considered. With the help of AI and robotics, humans may realise their full potential, work more efficiently, and go beyond basic thinking to develop cognitive powers comparable to those of humans.

Types of Robots

As their many shapes and capabilities attest, robots are incredibly adaptable mechanical beings. A few examples of the types of robots seen nowadays are:

- **Healthcare:** From physical therapy to aiding patients in walking, from navigating facilities to delivering vital supplies like medications or linens, robots perform a wide range of tasks in the healthcare business. By creating respirators and filling and sealing testing swabs, healthcare robots have even helped in the continuing battle against the epidemic.
- **Homelife:** To discover a robot in someone's home, all you have to do is search for a Roomba. However, modern house robots are capable of more than just cleaning floors; they can even mow lawns and enhance voice assistants like Alexa.
- **Manufacturing:** The manufacturing industry was an early adopter of robots, including the devices used on assembly lines for automobiles. Arc welding, material handling, steel cutting, and food packing are just a few of the many jobs that industrial robots can do.
- **Logistics:** Everyone wants their internet purchases delivered promptly, if not earlier. Therefore, businesses utilise robots to do tasks such as retrieving items from storage, stacking shelves, and even making short-distance deliveries.
- **Space Exploration:** Robots like Sojourner and Perseverance explore Mars as part of space exploration. Like Voyager and Cassini, the Hubble telescope is a robotic spacecraft.
- **Military:** Robocops take care of risky work, and it doesn't get much harder than contemporary combat. The military now has access to a wide range of robots that can do the more dangerous tasks that come with being a soldier. A few examples are the Centaur, a robot that searches for explosives like mines and IEDs, the MUTT, a robot that accompanies troops and carries their equipment, and SAFFiR, a robot that puts out fires aboard naval warships.
- **Entertainment:** there are already robot sculptures, toy robots, even robot restaurants on the market. You may anticipate that the entertainment value of robots will increase in tandem with their level of sophistication.
- **Travel:** The phrase "self-driving vehicles" needs just three words to be spoken.

LITERATURE REVIEW

Wu, Minhao (2023) The death toll and monetary damage caused by natural disasters are both substantial. Ineffective rescue operations, for example, may greatly raise the post-hazard mortality rate, even if the government has suggested well-developed policies to swiftly manage catastrophes and properly organise recovery efforts. One emerging trend in the management and access to natural catastrophes is the employment of robots, made possible by the rapid advancements in artificial intelligence. As a result of disaster response robotics, rescue teams may be supplemented or even replaced in hazardous situations, which lessens the burden on human workers and the hazards they face. While there has been progress in the field of construction automation, a long way yet to go before disaster management and recovery can benefit from completely autonomous building. Alternatively, the knowledge gap and resulting misunderstanding may be efficiently addressed via human robotics cooperation, which has great promise. The article provides an overview of disaster response robotics, explains its many uses, and discusses the current state of the field as well as its potential future developments.

Pagliarini, Luigi & Lund, Henrik. (2017) The consumer electronics and electric vehicle industries have been at the forefront of the robotics sector's job creation surge in the last decade, and by 2020, the industry will be valued $100 billion—the same size as the tourist industry. In the field of rehabilitation, for instance, innovations in active prostheses, wearable robotics, exoskeletons, and rehab/therapy robots have led to a tenfold increase in the market size from 2010 to 2016. To sum up, robotics will play an increasingly important role in many fields in the next decade, and the intelligent automation phenomena will be propelled by robots that are capable of learning from people and performing difficult tasks. Consequently, the purpose of this study is to attempt to portray the future of this crucial area of market research and scientific development, as well as its potential applications.

Trevelyan, James & Hamel, William & Kang, Sung-Chul. (2016) Robotics experts have been toiling away at a long-sought goal for quite some time: creating robots that can conduct dangerous jobs that humans can no longer do. Chapter 60 is set against the backdrop of a future when disaster response robots rescue people from burning buildings or find trapped miners by digging through crumbled rock falls. Robots that can carry out mundane tasks in hazardous environments are the subject of this chapter's examination. Although researchers still face several obstacles, they have made great strides in some domains. Depending on the kind and level of danger, hazardous situations provide unique obstacles to getting things done. Radiation, poisonous pollution, falling items, and explosions are all possible dangers. The cutting edge of commercial feasibility is technology that specialized engineering corporations can create and market independently of researchers. Teleoperated robots used for underwater engineering and Explosive Ordnance Disposal (EOD) are located just within this boundary. When compared to human speed and dexterity, robots are often more cost-effective, even when considering the usual tenfold penalty in manipulation performance caused by the limitations of current telepresence and teleoperation technologies. Nevertheless, the majority of commonplace uses in potentially dangerous settings are still far outside the realm of practicality. Tunnelling, underwater engineering, underground mining, firefighting, remediating radioactive pollution, decommissioning reactors, and clearing landmines and unexploded ordnance are all areas with several outstanding issues.

ATA, Atef & Ferreira, N. (2021) Many great engineering applications have been developed and improved throughout the years in response to environmental and social concerns. Take the automotive industry as an example; with the introduction of industrial robots, which now do about 90% of the work in this sector, our daily lives began to change for the better. The world's population of seniors is on the rise, and as a result, we must attend to their requirements, especially since their children have abandoned them in the midst of our hectic lives. The field of mechatronics and robotics has a lot of potential to alleviate the plight of the elderly by giving intelligent answers to their everyday problems and amusing them during their lengthy periods of isolation at home. The elderly may rely on clever mobile robots that come on various platforms (wheeled or walking) to assist them get their meals and medication on time. The impact of environmental factors and societal demands on the genesis of novel ideas will also be discussed in this article. Although the name "robot" had not yet been invented, this presentation will also cover the concept and inspiration behind two robotic applications developed by Al-Jazari. Two such implements are the peacock fountain and the hand-washing basin. Despite their reliance on mechanical construction and fluid to regulate their mobility, the two gadgets were aesthetically pleasing and reminiscent of modern robotic uses.

The Effects of Robots on the Natural World and Efforts to Promote Sustainability

In addition to revolutionizing our daily lives and places of employment, robotics has had far-reaching effects on ecological preservation and green initiatives. The need to lessen human impact on the environment and safeguard it is growing, and robotics is showing great promise as a means to this end. Our ability to create a more sustainable future via the use of robots and their effects on the environment. The capacity of robots to automate and optimise industrial processes is one of its most important contributions to environmental sustainability. Robots can streamline production, minimise mistakes, and increase industrial productivity, all while reducing waste. Not only does this lessen manufacturing's impact on the environment, but it also makes less reliance on humans, which means fewer accidents on the job.

The transportation sector is not the only one seeing robots' revolutionary impact. Reducing the number of cars on the road via the development of autonomous vehicles may alleviate traffic congestion and pollutants. By enhancing safety, efficiency, and environmental friendliness, this technology may completely transform the transportation industry. Robots are also having a major influence on the agricultural sector. Farmers may lessen their impact on the environment by cutting down on pesticide and fertilizer usage with the help of autonomous machinery and precision farming practices. A sustainable food supply for years to come may be achieved via the use of this technology, which can boost agricultural yields while simultaneously decreasing waste.

One way that robots are helping the environment is by producing energy. One way to lessen the environmental impact of energy generation is by using solar panel cleaning robots to ensure that the panels are always clean and working at their best. Further, robots may improve the safety and efficiency of energy production, which in turn reduces energy costs and increases the usage of renewable energy sources. Robotics is also having a big impact on environmental sustainability via its use in garbage collection. We can improve the effectiveness of trash sorting and recycling with the creation of autonomous sorting devices, which will decrease the amount of trash delivered to landfills. A cleaner environment is possible since this technique may lessen the number of pollutants that landfills produce.

Advantages and Disadvantages of robots

Each of them has advantages and disadvantages. The following are a few of them:

Advantages:

- They are reliable, precise, and consistent in their job.
- They are self-motivated and can work nonstop for long periods of time.
- Their sensors and actuators outperform those of humans.

Disadvantages:

- They are replacing people in many automated processes; however, they are not easy to programmed to do different jobs at different times.
- Advanced robots need a large budget for handling and maintenance.

What role does artificial intelligence play in robotics in the future?

With the help of AI, human-robot interaction, cooperation possibilities, and overall quality are all enhanced. Collaborative robots (co-bots) that assist humans with testing and assembly are already in use in manufacturing. It was originally intended for robots to act more like humans, and recent developments in AI have made this goal a reality. Workforce integration and productivity are both enhanced by robots that mimic human behaviour and thought. With the use of AI, robot designers are able to provide their creations with additional skills such as:

- **Computer Vision:** Robots are able to see and distinguish various things, pick up on finer details, and even figure out how to go around certain obstacles.
- **Manipulation:** Artificial intelligence enables robots to train their fine motor abilities, allowing them to manipulate items with precision and safety.
- **Motion Control and Navigation:** Robots can now navigate and control their own movements without human intervention. Thanks to AI, robots can now explore their surroundings on their own. Even in the digital realm of software, this skill is applicable. Artificial intelligence aids software robotic processes in avoiding exceptions and flow bottlenecks.
- **Natural Language Processing (NLP) and Real-World Perception:** The combination of AI and ML with Natural Language Processing (NLP) and Real-World Perception allows robots to perceive their environments more accurately, spot patterns, and analyse data. These upgrades make the robot more independent and less dependent on humans.

PRODUCING ROBOTIC SYSTEMS FOR SIMPLE ENVIRONMENT SAFETY

The development and display of innovative small robotic systems that can interface with high-speed ad hoc wireless communication networks and multi-purpose micro-sensors packed in three-dimensional ceramic. Reduce the potential for human and financial harm by using this technology for security and archaeological purposes, as well as for real-time monitoring and exploration of folded spaces in potentially hazardous environments (e.g., those with high levels of chemical leakage, pressure, temperature, and gas concentration).

Djedi Robot: A Rover for Exploring Pyramids

As far as ancient civilizations go, the Great Pyramid of Giza stands alone. There are three levels to the pyramid, one of which is reserved for the royal family. Both rooms feature airshafts, but unlike the king's chamber, the queen's shaft doesn't seem to serve any particular function and doesn't even touch the outside of the pyramid. In order to uncover the secrets of its purpose and construction, specialised mobile robotic tools were needed for exploration of the northern and southern airshafts. One such tool was the Djedi Pyramid Explorer Robot (Figure 1), which successfully completed a video survey by climbing the entire length of the southern airshaft in May 2010.

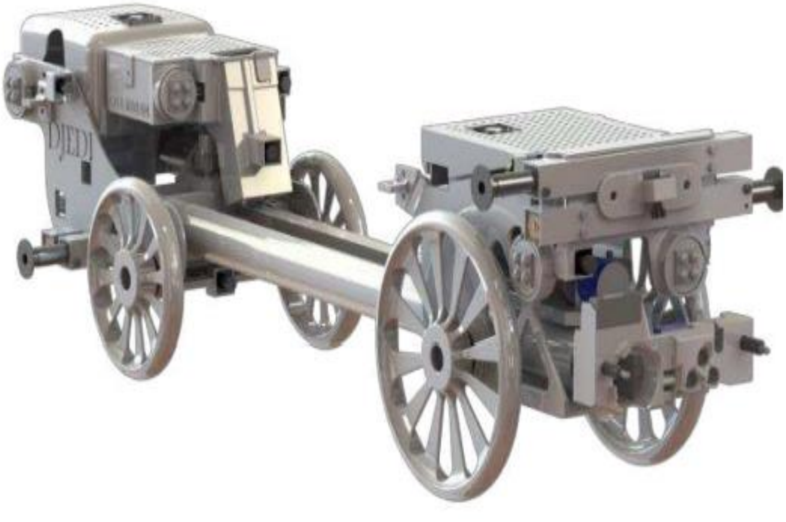

Figure 1. Rover from Djedi's Southern Shaft

The air shafts are about 210 mm × 210 mm and span through varied configurations for the northern and southern shafts. They are made of soft limestone with changing surface roughness. The southern shaft starts at the chamber entrance and runs horizontally for about 2 metres before rising at an angle of 40 degrees from the horizontal for around another 62 metres. At around 30 metres or 59 metres, there is a 40 mm vertical step, and at the very top of the shaft, there are two main objectives—two limestone blocking stones, one about 60 mm thick and the other about an unknown thickness—spaced about 200 mm apart. Additional obstacles are present within the shafts as well.

The Perfect Inclines to Climb

In order for a small exploration robot with mass Mr to climb an angle θa, it has to provide enough pulling force Fp to counteract the forces of gravity Fg, frictional drag forces Fd, and the forces needed to draw the tether Fc. One component of the gravitational force runs perpendicular to the ground, while the other component runs parallel to the ground.

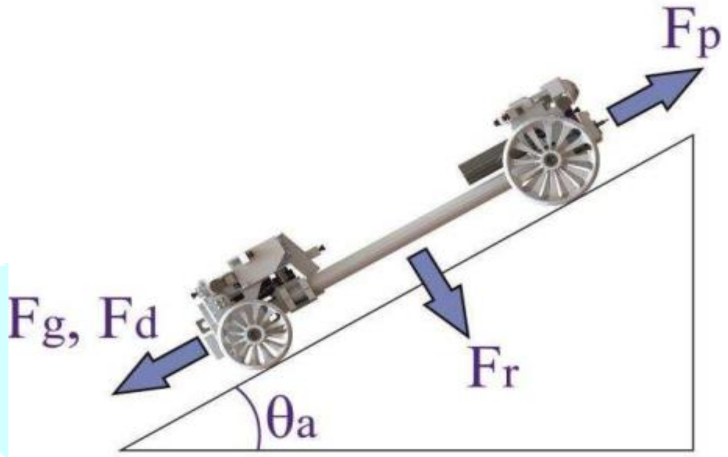

Figure 2. An incline-based free-body schematic of a robot

For a free body diagram, these equations hold:

$$F_r = M_r.g.\sin(\theta_a) \quad (1)$$

$$F_g = M_r.g.\cos(\theta_a) \quad (2)$$

Frictional coefficient (μn) and normal force (Fr) are the factors that restrict the pulling force (Fp) that the robot may exert on the floor.

$$F_p \leq F_r.\mu_n \quad (3)$$

To get beyond the tether's frictional drag (Fc), you have to add together all the forces caused by the cable. The cable weight is Cm, where xc is the length of the tether in metres, and μc is the friction coefficient between the cable and floor. Then, the force that must be applied to overcome the cable's frictional drag is determined by:

$$F_c = C_m.x_c.g.\sin(\theta_a) + \mu_c.C_m.x_c.g.\cos(\theta_a) \quad (4)$$

Hence, the necessary pulling power to ascend the slope is:

$$F_p = M_r.g.\sin(\theta_a) + C_m.x_c.g.[\sin(\theta_a) + \mu_c.\cos(\theta_a)] \quad (5)$$

Raising the friction coefficient (μn) between the robot and floor and lowering the friction coefficient (μc) between the tether and floor is the simplest way to make the robot more capable of climbing steep inclines. The tether for the Djedi robot was tailor-made with a thin sheath to minimise friction. The inch-worm mechanism allowed the four linear actuators to provide the necessary normal force (Fr) to overcome the opposing forces, resulting in a minimum weight (Mr) for the robot. In contrast, the tracked versions of Minebot and Letterbot will use the robot's bulk to generate enough traction force.

DIFFERENTIAL ROBOT PURE PURSUIT ALGORITHM AND ITS USAGE IN AGRICULTURAL ROBOT

An early technique for autonomous tracking on robots was the pure pursuit. It relies on predetermined locations, or waypoints, that the robot will traverse sequentially until it reaches the final waypoint. In this geometric method, the vehicle takes on the role of a lookahead point along its route. The curve between the lookahead point and the robot's present location is used to compute the steering angle that is necessary to reach the route. We have covered the theory of the PPA algorithm in this part. Other technologies of agricultural robots have been contrasted with wheel-based robots.

A Two-Wheel Differential Mobile Robot Mathematical Model

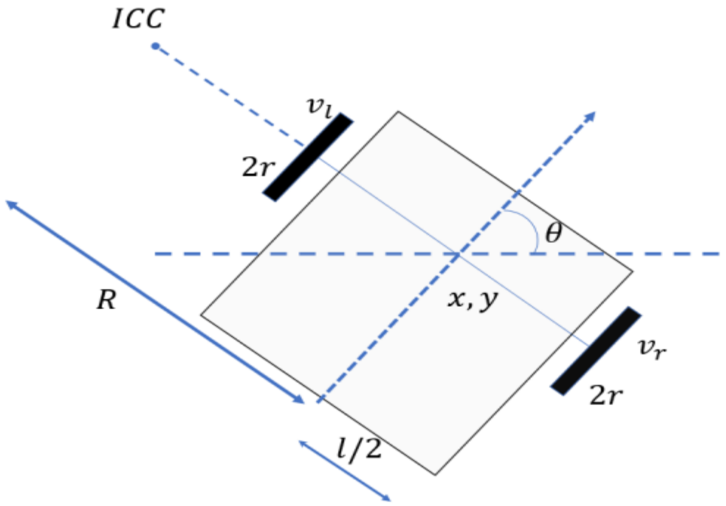

Figure 3. Drive kinematics of differentials

The robot's left and right wheel speeds may be adjusted to modify its direction. Equations (6) and (7) may be expressed for both wheels by calculating their rotation around the ICOC Instantaneous Centroid of Curvature:
ω=(R + l/2) = vrw (6)
ω=(R + l/2) = vlw (7)
The distance from the ICC to the centre point of the wheels, and vlw and vlw are the velocities of the right and left wheels, respectively, as they travel along the ground. The measure of the wheelbase is Ln. Using the formulae in equations (8) and (9) we can calculate R and at any given time:

$$R = \frac{(v_{rw}+v_{lw})}{2(v_{rw}-v_{lw})} \quad (8)$$

$$\omega = \frac{(v_{rw}-v_{lw})}{Ln} \quad (9)$$

Analysis of Multiple Path Tracking Algorithms in a Comparative Case

Using three distinct route tracking algorithm methodologies, we tried to drive a 2-wheel robot (front and wheel). Figure 4 provides a geometric representation. Assume that, given an N-point number of objectives, angle β i falls within the interval [α min , α max] of all possible angles, which are likely the limits of the wheel's angle. One may compute a set of curves, using ρ i = −2/α i for each curve and Ci for each curve's centre point. The distance from the target point to the line segment is determined by Ci, Gk. Gk, the normalised difference between the length of this segment and the radius, gives the d-distance from the curvature.

$$d_{sum} = \sum_{k=0}^{N} \left| \|C_i, G_k\| - \rho_i \right| \quad (10)$$

Its measure for selecting an appropriate angle is the sum of the differences given by eqn. (10) for each target point. The ultimate choice is the curve with the smallest dsum. If the look-ahead distance was greater, the vehicle's speed was raised; if it was shorter, the speed was maintained low.

- **Pure Pursuit Controller:** The Pure Pursuit controller employs a fixed-distance ld lookahead point on the target route to decrease the cross-track error de.

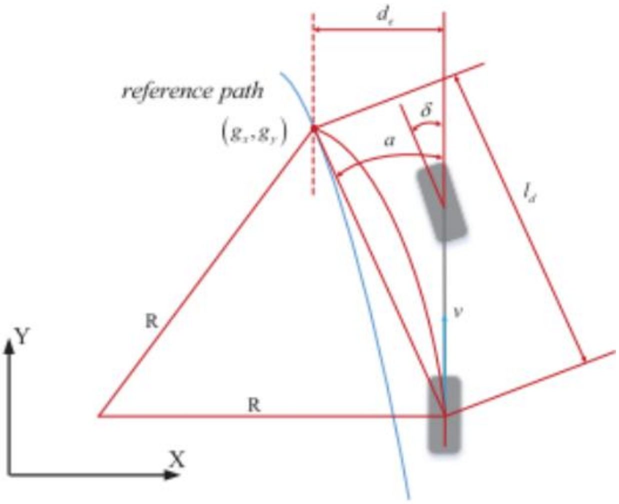

Figure 4. Geometrical depiction for 2-wheel robot

- **The LQR Controller:** Regulation of linear and quadratic functions. It is just an automated way of finding a good state-feedback strategy, and it saw extensive application in autonomous wheeled mobile robots. This stage involves building the controller that will be used to monitor the reference trajectory. To begin, the x-expressions for the location error and the orientation error make up the error vector e. As seen in equation 11, the formula for the transformation of the error state is T,

$$T = \begin{matrix} s \\ d_e \\ \theta_e \end{matrix} = \begin{bmatrix} -cos & -sin & 0 \\ sin & -cos & 0 \\ 0 & 0 & 1 \end{bmatrix} e \qquad (11)$$

- **Model Predictive Controller:** Controller for Predictive Linear Models an MPC controller consists of a model for trajectory errors, a constraint on the system, and an optimisation objective. On display in the error model is the tracking control system and its underpinnings. Constraints on the system cause the control signals to be constant. Building the optimisation aim takes system stability and route tracking speed into account. Equation (12) provides the model for the autonomous vehicle.

$$\begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} cos\theta \\ sin\theta \\ tan\, \delta / l \end{bmatrix} v \qquad (12)$$

Research and Insights for Evaluating Different Path Tracking Controllers

Key findings were derived from the experiment. Distance travelled, execution time, and deviations made while journey are represented by Dist_{trv}, Time_{exe}, and Dev%, respectively. The algorithm's performance may be evaluated using these three metrics. Table 1 displays the readings. The overall distance travelled by the robot to attain its objective is shown by the distance travelled. As a measure of the total oscillation and overshoots impacting the robot, a higher Dist_{trv} indicates a greater amount of travelling overshoot induced by the technique. An increase in the value of Dist_{trv} results in a greater Dev% and, thus, inefficiency. Since the agricultural road is mostly straight, the most significant source of deviation, other from oscillations, is overshoots at corners and curves.

Table 1. Analysing the effectiveness of different tracking algorithms

		PPA	**MPC**	**LQR**
Vel1=1.5(km/hr)	**Dist_{trv}(m)**	123	122	122
	Time_{exe}	310	410	330
	Dev%	2	1	1
Vel2=2.5(km/hr)	**Dist_{trv}(p)**	127	123	124
	Time_{exe}	182	405	302
	Dev%	5	2	3
LhD$_1$=4m	**Dist_{trv}(p)**	124	123	124
	Time_{exe}	221	405	301
	Dev%	3	2	3
Vel=2(km/hr)				
LhD$_2$=8m	**Dist_{trv}(p)**	129	124	125
	Time_{exe}	232	405	301
	Dev%	8	2	3

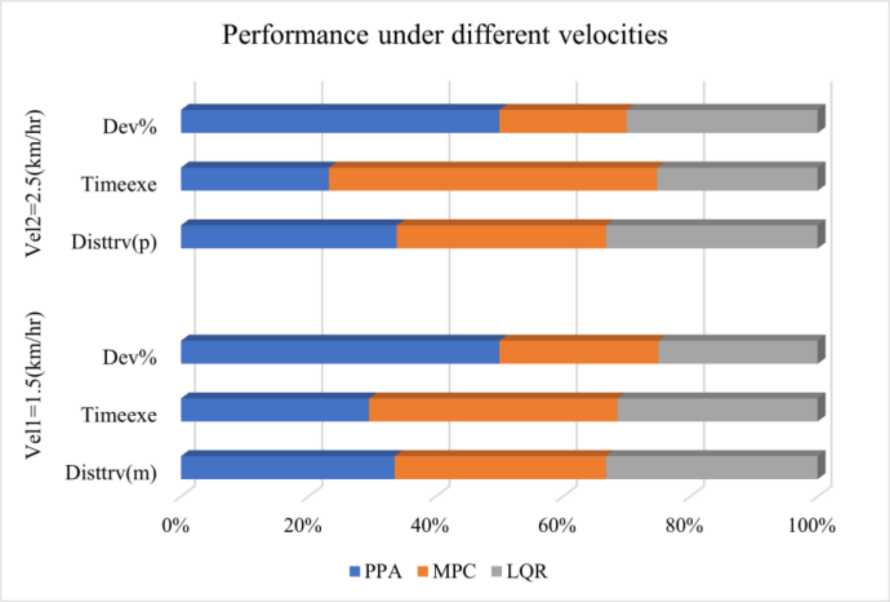

Figure 5. the robot's performance at various speeds

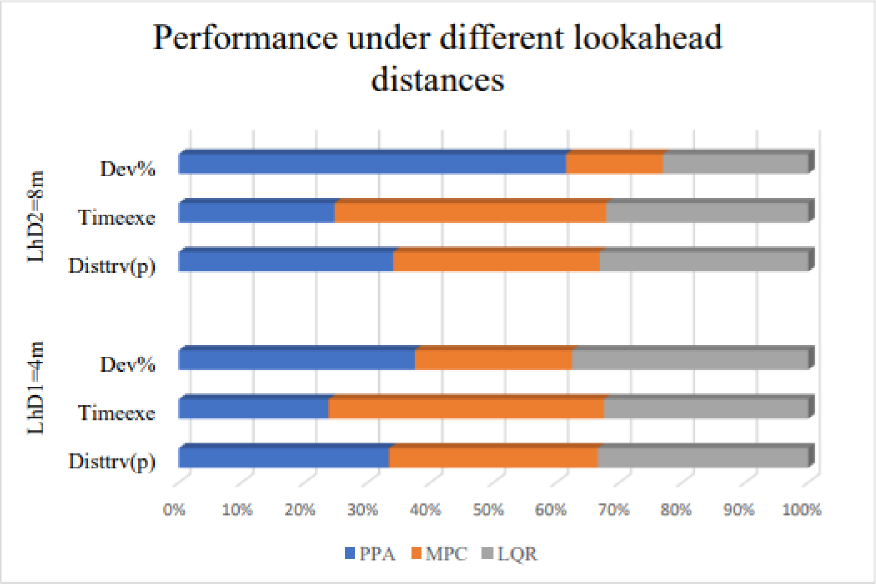

Figure 6. Performance graph for various time intervals

Figure 5 shows that when the velocity is raised, the PPA algorithm's Dist_{trv} and deviation are larger, but the time of execution Time_{exe} is low compared to the LQR and MPC algorithms. The mobile robot's kinematic model is identical to that of a free omnidirectional wheel or a castor wheel. Robotic capability is unaffected by obstacles that hinder the path of the rear castor wheels. Agricultural vehicles are best served by researching differential drive robots. Importing robot navigation technology from other sectors and applying it directly to agricultural engineering would surely drive up the cost of agricultural robots.

CONCLUSION

We can sum up that the world of tomorrow will consist of robots, it seems. Whether it's travelling to Mars for exploration or just choosing something, they're everywhere. Even if robots can't yet defeat humans, their technology will advance because to advancements in computer vision and natural language processing. This robot can help humans keep an eye on different kinds of locations, investigate them, and take measurements of their physical characteristics. Robots are capable of incorporating reconfigurable high-speed wireless communication networks, sophisticated navigation systems, multi-purpose sensors and actuators packed in 3D ceramic, and other advanced technologies. The intended uses include real-time monitoring and rescue in dangerous locations, such as deep mines and pipe and tube networks, with the goal of drastically lowering the risk of human and financial damages. At the same time, the output and benefit value will be affected by the actual production. Thus, it is critical to address the public's need for agricultural robots with accurate navigation while simultaneously introducing state-of-the-art technology to the sector at an affordable price. While MPC and LQR controllers do see some performance gains, PPA's geometrical-based solution necessitates much less mathematical processing.

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