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Review of Designing a Mobile Robotic Model by Using More Number of DOFS to Enhance the Robotic Motion

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ABSTRACT:
Robots is a humanoid machine that performs a specified task based on its displacements in workspace by satisfying the constraints like structure, geometry, and dynamics rotational systems. Control of robot motion is known as motion planning which becomes active research topics. Navigation control of the mobile robots are explored for tracking and selecting the optimal path. In path planning, achievement of collision free path is by smooth travel between initial and final points of rotational axes. The organized path is then tracked for rapid and reliable communication process. Degree of freedom is one of the main criteria for enhancing the navigation controls of mobile robotic motion. This paper is a review of designing mobile robotic model using DoFs, so as to enhance the robotic motion. Several approaches and techniques are been suggested by other researchers. It is noticed that artificial intelligence techniques widely adopted for optimizing the planned path. Evolutionary programming and neural networks are prevailed for assessing the optimal path with collision free and efficient task completion systems. This paper will assist the upcoming researchers to gain insight about the challenges in improving robotic motion by designing mobile robots.

Keywords: Robots, Collision free, Artificial intelligence, Degrees of Freedom, Navigation control.

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I. INTRODUCTION

Robotics is emerging rapidly due to enormous advancements made in technologies. The study of analysing the different motion of robots is becoming a research area. Nowadays, different types of robot are designed, so as to accommodate easy lifestyle. The main idea behind the robots design is too precise and optimize the human tasks. Mobile robots [1] is one of the recent research area which is focussed in all sorts of realistic scenario of industry, military and security environments. It also designed for entertainment as well as guidelines purposes. A mobile robot is an intelligent machine that can coordinates all locomotion's. Mobile robots are capable to navigate anywhere irrespective of its location. Different research questions like cognition, localization, navigation and so on are fine-tuned based on laboratory requirement. Commonly, robots can functions either autonomous (or) semi-autonomous. Collectively, mobile robot is defined as 'a mobile machine presented to real world, interacts via sensors and actuators and then perform its tasks with some intelligent agents [2].

Mobility patterns of the robots is measured byDegree of Freedom (DoF) [3] that estimates the number of dependent as well as independent variables, so as to specify the locations of all links in robot space. Any objects in space has six degrees of freedom. Objects moves in linear movement as well as rotational movement with three axes in linear form. Henceforth, body moved towards the objects in space with three linear movements and the three rotational movements takes place on oriented position. Since mobile robots are being widely used in factory environments, there is an urge for designing an automated robots. Navigation of a mobile robots includes perception of environment, localization & map building, cognition & path planning and motion control. Perception portrays the understanding towards sensed data, and then localizing by its pose (or) configuration of its surroundings. Cognitive decision making systems [4] makes for planning the path that accomplished for all tasks by motion controlling. Different methods of control of mobile robots are available,

a) Taguchi methods
b) Fuzzy logic controller
c) Neural network controller
d) Line follower robots
e) Wall following robots

Motion planning of a robot is one of the important area of designing the behavior of the navigation controls [5]. The main task of the robot is to complete its tasks with minimized time and distance. Pertaining to this, different criteria like computational complexity and power consumption has to be addressed. Mobile robot path planning is a significant issue in the field of independent robotic utilization distribution of materials, robot soccer in a manufacturing environment which is integrated with computers. Determining the path free of collisions for the mobile robots between its end points (start and finish) along the presence of obstacles is a well-known environment being explored by the scientists over the years with the help of various meta-heuristic and heuristic algorithms like TABU, A*etc., [6]. Majority of the scholars have designed algorithms depending on the intuition for suiting the specified environment. In a similar manner the polynomial equations can likewise be applied for developing the strategy of path planning. The parametric form of the Bezier equation is frequently utilised in computer graphics and associated areas. A parametric curve equation would express the curve coordinates as the variable function. The equation of Bezier curve could be easily manipulated. There are lesser turning points in bezier curves thus making it smoother in comparison to the curves of cubic spline. Because of these attributes, the equation of Bezier curve can be utilized for path planning applications of mobile robots. The Bezier curves also allow the controlling of their shapes quantitatively by the manipulation of the control point position [7].

Mobile robot is a robot type that can react, sense and move in a given situation. Navigating the mobile robots helps in controlling the robot movement from the start to end within the specified environment with obstruction evasion abilities. In view of the volume of available data about workplace, the path planning can be bifurcated as online and offline path planning. The robots will have prior information of the environment in case of global or offline path planning but the robot will not have any prior information in case the path planning is online [8]. There exist various offline path planning algorithms, for example, cell decomposition, visibility graph, artificial potential field and so forth. In cell decay, the roadmaps experience issues in resolving complicated conditions because of their significant calculation cost. It has been utilized for applications searching hazardous targets, for example, detecting landmine, fighting the fires and military observation and viable robotic issues [9]. The meta-heuristic algorithm like PSO could be incorporated for issues of path planning. Dijkstra algorithm might be utilized for developing the paths. In short, heuristic algorithm, cognitive layers, perceptual, sensor, motor are the areas of interest in association with robots. The parts of hardware, software and related techniques including various calculations to understand the objective or task is covered by mobile robotics.

1.2. Challenges in mobile robots:

There are various kinds of robots dependent on their applications that are inclusive of educational, medical, transportation, space exploration, industrial, and manufacturing robots. In the sectors that produce nuclear power and the manufacturing sectors, the human beings are exposed to hazardous conditions hence in these sectors there is a necessary demand for the robots [10]. For protecting themselves from the harmful impacts of loud noises, high temperature, radiation and so forth. People utilize substitute themselves with robots in conditions including dangers, redundancies, inconvenience, etc. With the progress of various technologies, the degree of the endeavours performed by robots is expanded with the objective that it is intriguing for machines for strengthening the capacities of humans and to replace them with robots for tedious and likewise perilous jobs. The robots without limits can be considered to have the brilliance of humans to the extent its structure, insight, cleverness and reactions are concerned.

1.3. Serial Vs Parallel configuration:

Robotic manipulators [11] are electronically controlled mechanical designs comprising of various portions that carry out tasks through interactions with the environments they are present in, generally they are referred to by the name robotic arms. Robot manipulators are widely utilized in the modern manufacturing industries and furthermore have numerous other specific applications. (For instance, Welding, painting). Robots can be bifurcated by different measures of selecting the robots, for example, DOF, kinematic structure, drive innovation for joints actuation, geometry of workspace, movement attributes and the kind of the control framework. In these kinds, the kinematics basic topologies deal with robot configurations that are closed chain, parallel chain, open or serial chain. The robot arms normally utilized in industries comprise kinematic structures of open-chain type. Such systems comprise of a chain of connections associated with joints. These are revolute joints that rotate around the prismatic joints or axis that move along the axis. Serial manipulator comprises of a few series connected links by methods for different kinds of mechanical joints, ordinarily prismatic (straight) and revolute in this design commonly one piece of robot is appended to the ground and the other part is allowed to move in space. The robot's fixed link is known as base and free end is where the mechanical fingers or gripper is joined from end effector. For issues including positional examination of serial robots, the forward kinematics is genuinely basic, though the reverse or inverse kinematics turns out to be extremely troublesome. While, parallel manipulator is close loop component wherein end effector is associated with the base by a minimum of two free kinematic chains. A completely parallel manipulator is also close loop system with 'n' DOF, end effector associated with the base by 'a' chains that are independent having maximum two links and are incited by unique rotary or prismatic actuator.

II. LITERATURE REVIEW

This section presents the reviews of prior techniques established in robotic designs. Different methods employed in mobile robots are explained as follows:

2.1 Taguchi method:

Taguchi and Konishi developed a statistical technique referred to as Taguchi technique. At first it was created for improving the quality of the produced merchandise (development of manufacturing process), later the application of this method was extended to numerous different areas of Engineering, for example, Biotechnology [12] and so forth. Proficient statisticians have recognized Taguchi's endeavours particularly in the improvement of structures for the study of variation. Successfully accomplishing the ideal outcomes includes a cautious determination of procedure parameters and classifying them into noise and control factors. Selecting the control factors have to be made with an objective to nullify the noise factor effect. Taguchi Method includes identifying appropriate control variables to get the ideal outcomes of the procedure. Symmetrical Arrays (OA) are utilized for carrying out various experiments. These experiment results are utilized to assess the information and foresee the nature of produced components.

2.2 Fuzzy logic controller

The fuzzy controller developed oversees simultaneously that tasks of obstacle avoidance and navigation. Numerous scholarly investigations propose the fuzzy controller hypothesis as an answer for controlling the mobile robots. Its fundamental structure comprises three blocks: defuzzification, inference, and fuzzification. The initial stage for realizing a fuzzy controller is fuzzification that changes the input, output of every genuine value into membership grades for the terms of fuzzy control. The subsequent stage is fuzzy inference that integrates the procured facts of fuzzification of the standard base and carries out the process of fuzzy reasoning. There are a few strategies for fuzzy inference relying upon the utilizations and membership function form. At the point when the variables of input, output are characterized, the rule of fuzzy is introduced as the accompanying structure: IF 〈 antecedents〉 THEN 〈 conclusions〉 rules. The last stage is defuzzification. The goal of this stage is transforming the output subsets computed by inference engine.

2.3 Neural network controller

Controlling mobile robots using neural networks has as of late been the subject of extreme research [18]. It is regular to work with kinematic models of robot to get steady movement control laws for reaching goals or following trajectories. Majority of the authors tackled the issue of stability and control of motion for mobile robots utilizing the algorithm of nonlinear back stepping. Fierro and Lewis built a neural system based model that was a combination of torque controller and back stepping tracking, utilizing a multi-layer feedforward neural system, where the neural system can learn from the mobile robot dynamics by its technique of on-line learning. However, the algorithms of control and the neural network are complex and costly with respect to computation. A controller based on neural network of single layer for robots was proposed in [19]. This methodology excludes any non-holonomic kinematics, hence cannot be utilized for robots with kinematic restrictions. But, the issue of controlling mobile robots has attracted many researchers in perspective on its hypothetical difficulties. Indeed, these frameworks are cases of non-holonomic systems because of the constraints of perfect rolling (no lateral slipping or longitudinal of wheels). The below mentioned assumptions are made while designing the velocity controller for mobile robots:

- Arbitrary speed can be accomplished instantaneously.
- 1st order differential equations captures the Kinematic model.

2.4 Line follower robots:

Line follower robots are mobile machines that could detect and follow the lines which are drawn on the floor. Usually paths are predefined and could be noticeable like dark lines on white surfaces or not visible similar to magnetic fields. Unquestionably, this sort of robot should detect the line using sensors of infrared ray (IR) [13] that are installed on the lower side of the robots. From that point forward, the information is transmitted to the processor by particular buses of transition. Consequently, the processor will determine the appropriate commends and afterwards, it sends them to the driver and in this manner robot will follow the path [14]. Usually LFRs are mobile machines that operate on their own following the lines that are drawn on the floors. The path will be a line of white or dark colour based on the floor color. The fundamental tasks of the LFR are as per the following:

1. To capture the position of the line using the optical sensors that are placed in the front part of the robot. Majority are utilizing a photo-reflectors, and image sensors for processing the images. Along these lines, the process of line sensing requires high robustness and high resolution.
2. To steer the robots to detect the line with the help of any of the steering mechanisms. This is only a servo activity; but there is a need for compensating the phases so that motion tracking is stabilized by the application of any servo algorithms or PID filters.
3. To control the speed based on the conditions of the path. The speed is constrained while passing the curve as a result of friction between the floor and tire.

Better techniques can thus improve the intensity of manoeuvre. Subsequently the speed of the robot can be increased. Hence, increasing the performance of the robot [15]. This sort of robot can be utilized for military purposes, transportation frameworks, delivery services. Besides, there are numerous yearly LFR competitions carried out by colleges or companies around the globe. They generally ask the robotic groups to develop a small robot with the mentioned weight and dimensions as per the rules of the competition. In reality, the LFRs are the most favoured robots yet unquestionably the precarious part is to make the LFR's response smooth and quick.

2.5 Wall following robots:

The control issue in WFR is represented by moving the robot along the walls in the desired directions along with maintaining a specified distance to the wall [17, 20]. This can be the situation in the below mentioned circumstances.

Following an unknown wall: If the environment knowledge is very less or nill, trajectory will be specified to follow the wall present on the right till the first doorway is reached. In case the main objective of the robot is world modelling then its required for following the wall so that it is modelled completely. Dead reckoning is used for calculating the robot position.

Following known wall: If the robot trajectory is already planned, it tends to be trailed by dead reckoning methods. But dead reckoning strategies experience the ill effects of accumulation errors. An approach to ensure these errors are small is by wall tracking. The plan should include wall availability in the described route of that case. This is the opposite of the prior case: presently the wall position should be known precisely.

Obstacle avoidance: If the sensors are unable to provide the size or shape of the obstacle then evasive routes are not possible. Hence making it necessary for following the obstacle contour till it is possible or till the robot can resume the original route.

III. COMPARISON OF RECENT TECHNIQUES

The comparison table provides the various design parameters of robotic models.

Ref. Nos	Techniques	Merits	Demerits
[21]	Cable Driven Parallel robots were taken for study. T-Bot techniques was employed with three pairs of cables. Optimization of kinematics was analysed for performance enhancement. Force transmission with end effector has been devised. Force transmission index is the metric computed for experimental purpose.	Good trajectory tracking Accuracy was achieved, even with the minimized boundary space. Likewise, displacement time was also lowered.	If the diameter of task workspace increases, then the motion takes maximized distance. High frequency time taken with high power consumption.
[22]	Disassembly line balancing solution was improved for remanufacturing applications. An improved discrete bee's algorithm was developed for	Performance of the bee's algorithm with dynamic populations was explored. Best cycle time was achieved under three optimization functions.	So as to achieve best cycle time, a higher number of iterations are taken for limited population.

	planning the motion sequences. Here, robotic workstation assignment matrix is computed for assigning respective weights to different indicators.	Space inference matrix is easily deduced the spaces for working robots.	
[23]	Simulation based optimization model was designed for robotic tasks. It has been observed that some uncertainties occurs in Gripper design. Thus, it was optimized for criteria's of industrial environment. Coordinate descent and the Conjugate gradient are used for joining the robotic motions.	System has ensured better surrogate function. Multiple evaluations are analysed for ensuring the robustness.	Cut-out design is not properly fitted into cylinder, then the alignment in gripper changes in an unpredictable manner. Standard errors has greatly influenced by outliers model.
[24]	Optimizing the topology for point robots moving systems was studied under moving path and heat transferring paths. Obstacles placed in heat source and heat sinks has adaptively increased the thermal compliance. Thus, conductivity spreading approach was framed for devising the ground structure.	Less time taken for robot navigation.	System takes higher computational resources. Also increases the computational burden of the simulation environment.
[25]	Energy consumption rate is higher in industrial robots. A novel simulation tool was designed for optimizing the energy at both online and offline phases.	It has maintained the same productivity and manufacturing quality. Motion parameter was easily estimated under different loadings.	It has compromised the final cycle time during energy optimal operation scheduling.
[26]	Performance of the swimming of robotic fish was explored for improving swimming speed and the propulsive efficiency. Newton Euler method was designed with Central Pattern Generator (CPG) networks that exactly located the swimming coordinates.	Explicit swimming modes are enabled to handle the vast acquisition of model parameters. Robotic fish adaptability is increased for different swimming conditions with lessened iterative functions.	Steering gear takes higher mechanical configuration. Too high frequency observed that affects the amplitude coordinates.
[27]	Neuro-dynamic approach was framed for connected undirected graphs that resolved the convex problem.	Tracking accuracy was improved for all rigid object body.	Some transient behaviours developed higher error process.
[28]	Mobile radiation affects the workers and thus, beetle antennae search algorithm was suggested for radiation and its protectional steps via radiation path optimization process. Target of each robots are utilized for avoiding the	This algorithm eliminates the high radiation from the target classes by assignment operators. Smoothing operators was used for finding the appropriate discrete points, so as to explore the optimized path.	High computational time is observed, even in simplified process. Most of the similar radiation emitting patterns are discarded that lowered the risk minimization process.

	radiation patterns. Heuristics search was performed to monitor their radiation pattern.		
[29]	Dust accumulation in photovoltaic has reduced the power functioning of the autonomous robot. Here, air solid two phase control equation was used for absorbing the dusts. In addition, distributing the pressure and dust particle was analysed for structuring the parameters.	Velocity and fan speed are the prime criteria taken for power generation systems. Relaxation factors under varying pressure was monitored. It is inferred that the flow of particles around the corner moves rapidly. Henceforth, the turbulence flow is easier with efficient workspace. Computational complexity is less.	Increase in necking radius has restrained the velocity flow, irrespective of outlet height. Though dust is absorbed easily, the error rate is not analysed.
[30]	Grasp behaviour of the mobile environment is a prime challenging issue. An under-actuated tendon-driven robotic gripper with two 3- phalange fingers and a geometric design optimization method was evaluated. Geometric dimensions of gripper was analysed for reducing the resistances. Here, three objectives, multiple geometric with two fitness models.	Genetic diversity under mutation operator has configured the workspace. It is easily adapted to the objects shapes under different compliances.	Fingertip grasp is not possible due to higher distal phalanges.
[31]	Cooperation between robots and human has imposed challenges in Front End Module (FEM), while handling the heavy objects. Wearable robots often requires the quality of type loaders. Henceforth, six bar linkage with toggle mechanism has been employed to reduce the weight of the gripper with maximized gripping force. Along with multi-objective optimization was also studied for exploring the coupler path and drive torque.	Pareto optimality functions is used for improving the driver efficiency and thus, it was achieved with better payload parameters selection. Actuator design is also lighter that reduced the gripper weights. Accuracy of the path is also improved.	Maximized the path difference has brought collision among the navigation controls.
[32]	Task based agricultural robot is explored by optimizing the harvesting process. Continuous monitoring of the robot structure and locations. Different modularity	It has maximized the harvesting rate of fruit with lessened low-utilization barrier. Trajectory planning is optimized that made the robot to locate easily.	Lowered accuracy is observed, when the location changes due to climatic scenario. Displacement angle of the robots has reduced the path optimization.
[33]	Mobile Painting robot manipulators is one of the research field that depicts the optimization of base position of robots. Coupling problem occurs in robots manipulators.	Axis availability has differentiated the non-coupled structure. It reduced the computational complexity with different cost functions.	Inequality constraint optimization problem has taken singularity constraints causes non-optimal solutions.

	Each robots is analysed under two aspects, internal penalty function which explored the base position. Then, Lagrange multiplier was computed to optimize the base position of robots. It was estimated for three different surfaces, i.e flat, cylindrical and truncated conical surfaces.		
[34]	Pose optimization method with 5 axis milling robot was designed for commercial robots. 3 points of rotational displacements was taken for increasing the stiffness of the robots. Discrete search optimization was taken for index maximization, smoothness in trajectory and the task completion time.	Accuracy of the system is improved with better localized robot trajectories. Stiffness is increased with smaller deformations and vibrations.	Smoothness of the trajectory at high pressure has deformed the edges and takes high time for task completion. Invariances in frames has also deformed the structure of the edges.
[35]	Biped robot walking is one of the humanoid robots. Generation of gaits needs to be stable to offer better performance under dynamic environment. Henceforth, Modified Differential Evolution and Adaptive Evolutionary neural models were designed.	Since the algorithm operated meta-heuristically, the irrelevant space in Cartesian products are minimized. Trajectory paths are designed strongly and thus, yielded better results than ZMP.	Walking stability has improved for limited joint angles. Fitness convergence for multiple joints is lowered in test results.
[36]	Different motion profiles has different navigation control has been studied. When the motion time alters, it greatly affects the production time. Thus, a simple energy consumption models was developed using Joule’s law. It is observed that the power loss occurs in three forms, copper losses, power on mechanical design, and consumption of constant energy. Here, 3 degrees of freedom was considered.	Minimized the energy loss in horizontal motions which is mainly responsible for motion accuracy. When the largest torques is applied in horizontal movement, then the intensive energy loss is achieved.	Under different acceleration, slow motions are not considered. Environmental consequences during production plant is not discussed.
[37]	Hydrodynamic performances of mobile robots in underwater has suffered from coverage issue that includes resistance and manoeuvrability. Henceforth, it requires a collaborative	Different rules are generated for optimizing each task of a robot. Meshes topology in hemisphere cylinder has increased the velocity inlet and outlets. Effective searching is achieved	Due to tasks overloading, the computational loads is also increased. Accuracy is not guaranteed.

	communication among the robots which is explored by artificial intelligent techniques and the particle swarm optimization. Here, design lines of the hydraulic parameters was improved with four degrees of freedom.	with globalized optimal solution.	
[38]	Structure modelling in closed loop and single degree of freedom using robot gripper mechanism. End-effector and joint coordinates are improved by aligning its geometric coordinates using Lagrange addition. Then, force of the gripper mechanism is explored by non-dominated sorting genetic algorithm. Here, 6DOF with parallel manipulator was taken for the study purpose.	Optimality was taken to enhance the stiffness and dexterity of mobile robots in parallel way. System ensured the maximized force transmission ratio.	Tolerance rate between actual and link lengths is not analysed properly when the objective function alters. Minimum gripping force is achieved only when the minimized design variable selected.
[39]	Path planning issue was resolved by adaptive particle swarm optimization method. Here, an obstacle is introduced for different objective function and thus the ability of robots was simulated.	Path time and the length is enhanced. Since inertia weight decreases, the local path is optimized at lowered time. Optimized robots reached the targets without bothering the obstacles.	When the mazing environment is changed, navigation control functions slowly until the obstacle invasion.
[40]	Knowledge based optimized tool was designed for automated solutions. It was implemented in German automotive supplier. Semi-structured data is classified efficiently using web ontology language.	Adaptability and maintainability of the knowledge systems is continuously monitored and updated in knowledge tool.	Since it followed monolithic architecture, scalability of the tool is not assured.

From the comparative table, the research problems pertain in this field are explored as follows:

a) Navigation is one of the significant and potential functions of the mobile robots. It includes self-localization, planning the path and constructing & interpretation of a map. Each feature has used in different applications for an efficient mobile robotic designs.

b) Exploration of terrain: Since different sensors are employed to monitor and explore the terrains of robots without any primitive information. In general, it explores all the boundaries of the environment based on its sensing capabilities. Henceforth, design of algorithms should focus on improving the sequential actions of robots and then optimized the performance of the robots in the field. During sensing operations, some irrelevant regions are also explored. This causes the void in workspace and internal structure of the design develops issues like lowered task completion time, multiples the Cartesian workspace and energy loss.

c) Coverage: It combines with terrain exploration, in specific to, it deals with the peripheral device dispersal of the environment. It depicts the navigation planning and coordination with the assistance of sensor, effector (or) a robot. It purely depends on coverage of area geometry of mechanical designs. Lowered efficiency of effector, low-range inspection device and decomposition of cellular are needs to be focussed for coverage trajectories.

d) Invasion of multi-robots: Usually, task completion time is initially assumed for all mechanical power and design. Due to some indoor coverage, it expels unstructured data due to dynamic behavioural changes. Henceforth, coverage and communication by a robot becomes more complex. So as to complete the task in a time, it should ensure a collision free with complete coverage.

e) Cellular decomposition: Though coverage issue is resolved by dividing the terrain space into grid cells for eliminating the overlapping regions, the chances of odometer errors are highly dispersed in robotic environment.

f) Centralized and Decentralized approaches: Multi-robot architectures are mostly used for mobility environment. Communication is an important aspects in multi-robot systems. Global and local communication in both approaches are to be handled properly for an interoperable environment.

IV. CONCLUSION

This paper is a review of design model of mobile robotic, so as to enhance the motion of the robots. As we know, degree of freedom is the main parameters in designing navigation controls of mobile robots. It's a kind of mechanical devices that takes count of dependent and independent displacements of the motion capabilities of robots. In general, 3 and 6 degrees of freedom were used for optimal design of the navigation controls. Here, several papers are collected and explored its used techniques, merits and demerits. The conducted reviews states the research challenges in the aspects of terrain explorations, coverage, multi-robots, centralized and decentralized models and cellular decomposition. In the literature, different optimization techniques were studied for optimizing the kinematic models, even in intelligent distributed behaviour. Mining of appropriate tasks and task completion time are mainly focussed in multiple autonomous mobile robots via efficient corporative and collaborative process.

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