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Applications of holonomic and non-holonomic constraints in modern technological innovations: systematic review

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Abstract: Holonomic and non-holonomic constraints are crucial aspects of geometric mechanics that are widely applied in modern technologies such as navigation, robotics, and autonomous vehicles. This study aims to answer two main questions: (1) How are holonomic and non-holonomic constraints distributed in modern technology fields? and (2) How do these constraints contribute to the efficiency and performance of systems? The method used is a Systematic Literature Review (SLR) following the PRISMA 2020 guidelines. Literature was collected using Publish or Perish software from Scopus, ScienceDirect, and Google Scholar databases, with specific keywords. Out of 165 articles initially found, 32 articles were selected for the final analysis after screening, removing duplicates, and evaluating quality and indexing. The analysis results show a dominant application of non-holonomic constraints in dynamic systems such as differential-drive robots and autonomous vehicles due to their ability to enhance flexibility and adaptability. In contrast, holonomic constraints are more commonly used in high-precision systems like omnidirectional robots. The implications of this study emphasize the importance of selecting the appropriate type of constraint to optimize the performance of geometric mechanics-based technologies.

Keywords: holonomic constraints, non-holonomic constraints, robotics, autonomous vehicles, navigation

1. Introduction

Mechanics is a branch of physics that studies motion and the interactions between objects and their environment. One important subfield of mechanics is geometric mechanics, which focuses on the geometric aspects of mechanical systems without considering external forces. Geometric mechanics explains how geometric structures and constraints affect the trajectory and motion configuration of a system (Firdaus et al., 2023). In practice, this approach is widely used in fields such as robotics, path planning, and precision motion control (Ariska et al., 2020). A central concept in geometric mechanics is constraint, which refers to limitations on the motion of a physical system that can be geometric, structural, or dynamic in nature (Rosyid, 2011). These constraints play a major role in determining how a system moves and interacts with its environment

(Hadi, 2022). The two most relevant types of constraints in the development of modern technology are holonomic and non-holonomic constraints. Holonomic constraints can be formulated in explicit equations involving only the system's coordinates (Todorov, 2014) whereas non-holonomic constraints involve velocities or other time derivatives and thus cannot be reduced to position-only relationships (Rosyid, 2011)

Both types of constraints have wide applications in modern technological systems. In robotics and autonomous vehicle systems, holonomic constraints are used for path planning and precise object manipulation (Wu et al., 2024), whereas non-holonomic constraints serve as the foundation for designing motion control and complex navigation systems (Yuniawan et al., 2021). Technologies such as automatic control systems and adaptive systems based on artificial intelligence also leverage constraint principles to achieve energy efficiency, stability, and adaptability to environmental changes (Aminullah et al., 2023). Although numerous studies have discussed the application of holonomic and non-holonomic constraints in various technological fields, a comprehensive systematic review that maps out the distribution of applications, differences in roles, and contributions of these two types of constraints to system efficiency and performance is still lacking. Most existing studies are highly technical and specific to particular fields, making it difficult for readers or other researchers to gain a holistic understanding of how these constraints are applied across disciplines in modern technology.

Based on the aforementioned background, this study aims to conduct a Systematic Literature Review (SLR) on the application of holonomic and non-holonomic constraints across various fields of contemporary technology. The primary focus is directed toward sectors such as navigation, robotics, vehicular systems, and dynamic system control areas known to be significantly influenced by the presence and characteristics of mechanical constraints. In addition to mapping trends and the distribution of applications, this study also seeks to critically examine the differing contributions of each type of constraint to system performance, particularly in terms of efficiency, accuracy, and technological adaptability. Specifically, this research is designed to address the following two main questions:

1. How are holonomic and non-holonomic constraints distributed across modern technological domains such as navigation, robotics, and autonomous vehicles?
2. What are the contributions of holonomic and non-holonomic constraints to the efficiency and performance of modern technological systems?

To answer these questions, this study adopts a Systematic Literature Review (SLR) approach, structured according to the PRISMA 2020 guidelines (Page et al., 2021). The literature is gathered from several leading academic databases, including IEEE Xplore, Scopus, and ScienceDirect. A rigorous inclusion and exclusion criteria framework is applied to ensure the relevance and quality of the sources analyzed. Each selected article is then thematically analyzed to identify patterns of constraint utilization, fields of application, and the effectiveness of their implementation in enhancing the performance of modern technological systems.

2. Methodology

This study employs a Systematic Literature Review (SLR) approach, structured according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al., 2021). This approach was chosen to ensure that the review process is systematic, transparent, and replicable. Literature searches were conducted using Publish or Perish version 7 software, which accesses reputable academic databases including Scopus, ScienceDirect, and Google Scholar. The keywords used in the search were *"Holonomic Constraint"* and *"Non-Holonomic Constraint"*, with the search specifically targeting article titles and abstracts.

The initial search results were screened to remove duplicate entries. A preliminary selection was then carried out based on topic relevance by reviewing the titles and abstracts to ensure alignment with the research focus, namely the application of holonomic and non-holonomic constraints in modern technologies such as robotics, autonomous vehicles, and other adaptive mechanical systems. The next step involved a more detailed selection process based on the following inclusion criteria (1) The article discusses the application of holonomic or non-holonomic constraints within the context of modern technology; (2) Published between 2020 and 2025; (3) Available in open access and in full-text format; (4) Not a seminar paper, book, or thesis. Articles that met all inclusion criteria were then analyzed using a thematic analysis approach, where findings were categorized based on application themes, advantages, challenges, and research trends (Riger & Sigurvinsdottir, 2016). The results of the analysis were then tabulated to facilitate interpretation and mapping of each article's contribution to the development of technology grounded in geometric mechanics. The article selection process—from identification to final inclusion—is visualized using a PRISMA flow diagram (Page et al., 2021), which documents each step of the systematic review process.

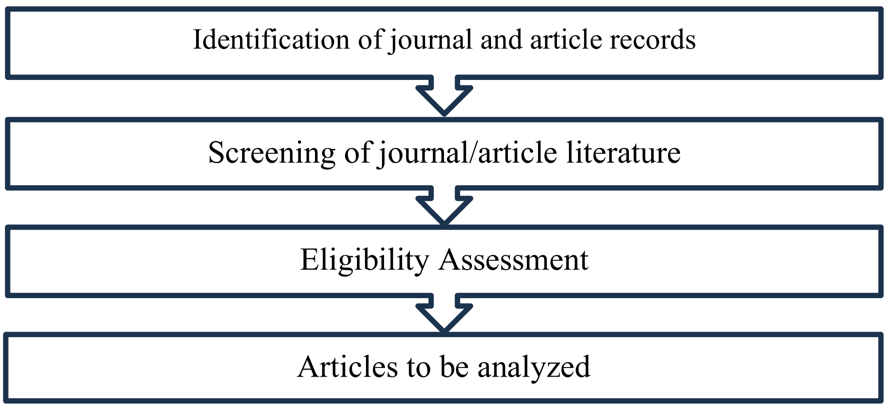

Figure 1. Research Flow Diagram

3. Results and Discussion

3.1. Results

This study employs a Systematic Literature Review (SLR) method with a PRISMA approach, as presented in Table 1.

Table 1. Selection Stage Results

Selection Stage	Number of articles
Articles initially found	165
title and abstract screening	120
Eligibility assessment	75
Articles included in the final analysis	32

Based on the PRISMA method, the literature search resulted in 165 articles at the initial stage. After the screening process and quality evaluation, as well as indexing (specifically in the Scopus database), 32 articles were retained and used for the final analysis. This selection process aims to ensure the validity and relevance of the publications analyzed.

3.1.1. Distribution of Holonomic and Non-Holonomic Constraints

In the initial stage of the analysis, an identification of the characteristics of the literature sources was conducted, including the ranking of the journals where the articles were published. This step is crucial to ensure the quality and credibility of the reviewed articles. Most of the articles came from journals or proceedings that do not have a quartile (Q) ranking. The details of the journal ranking distribution are presented in Table 2 below.

Tabel 2. Journal Ranking Distribution

Juornal Rank	Number of Articles	Journal Name
Q1	8	IEEE Access, IEEE Transactions on Vehicular Technology, GPS Solutions, IEEE Sensors Journal, Remote Sensing, Results in Engineering
Q2	6	Journal of Systems Engineering and Electronics, Measurement Science and Technology, Journal of Robotics and Control (JRC)
Not yet assigned Q	19	IEEE Access, 2023 8th International Conference on Robotics and Automation Engineering (ICRAE), Jurnal Inovtek Polbeng Seri Informatika, 2020 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Journal of Science, Technology and Engineering Research, IEE 2024 Tenth Indian Control Conference (ICC), 2021 IEEE/SICE International Symposium on System Integration (SII), Jurnal Nasional Teknik Elektro dan Teknologi Informasi, Jurnal Ilmu Komputer dan Agri-informatika, Journal Of Polytechnic-Politeknik Dergisi, Jurnal Ampere, Jurnal Otoranpur, International Journal of Engineering Research and Development,

Next, an analysis was conducted on the main focus of each article based on the type of constraint. The identification results show that non-holonomic constraints are discussed more frequently than holonomic constraints, as shown in **Table 3**.

Tabel 3. Distribution of Constraint Types

Constraint Types	Number of Articles
Holonomic	9
Non-Holonomic	23

This distribution was then further analyzed based on its application in modern technology. The mapping of applications based on the type of constraint is presented in Table 4.

Table 4. Distribution of Constraint Application Areas

Application Area	Holonomic	Non-Holonomic
Navigation and Localization	2	9
Mobile Robotics	6	9
Control Systems and Artificial Intelligence	1	5

3.1.2. Contribution of Holonomic and Non-Holonomic Constraints in Modern Technology

Based on the literature analysis conducted, it was found that both holonomic and non-holonomic constraints contribute significantly to various fields of modern technology. One of the most heavily focused areas is navigation and localization. A summary of constraint applications in the field of navigation and localization is presented in **Table 5** below:

Table 5. Constraint Applications in the Field of Navigation and Localization

Author(s)	Year	Title	Constraint Type
Wei Sun; Yihan Yang	2020	BDS PPP/INS Tight Coupling Method Based on Non-Holonomic Constraint and Zero Velocity Update	Non-Holonomic
Quan Zhang; Yuanqian Hu; Xiaoji Niu	2020	Required Lever Arm Accuracy of Non-Holonomic Constraint for Land Vehicle Navigation	Non-Holonomic
Andy Yuniawa, Indra Adji Sulistijono, Muhammad Rois	2021	Sistem Navigasi dari Holonomic Mobile Robot untuk Membantu Tenaga Kesehatan dalam Pengiriman Logistik kepada Pasien	Holonomic
Zhehua Yang, Zengke Li, Zan Liu, Chengcheng Wang, Yaowen Sun and Kefan Shao	2021	Improved robust and adaptive filter based on non-holonomic constraints for RTK/INS integrated navigation	Non-Holonomic
Yimin Xiao; Haiyong Luo; Fang Zhao; Fan Wu; Xile Gao; Qu Wang	2021	Residual Attention Network-Based Confidence Estimation Algorithm for Non-Holonomic Constraint in GNSS/INS Integrated Navigation System	Non-Holonomic
Mehmed Rafi Imamoglu; Ecem Sumer; Hakan Temeltas	2023	A Comparison of Local Planner Algorithms for a ROS-based Omnidirectional Mobile Robot	Holonomic

Author(s)	Year	Title	Constraint Type
Sixiang Cheng, Jianhua Cheng, Nan Zang, Jing Cai, Shilong Fan, Zhetao Zhang & Haoran Song	2023	Adaptive non-holonomic constraint aiding Multi-GNSS PPP/INS tightly coupled navigation in the urban environment	Non-Holonomic
Xin Li, Hanxu Li, Guanwen Huang, Qin Zhang & Shuolin Meng	2023	Non-holonomic constraint (NHC)-assisted GNSS/SINS positioning using a vehicle motion state classification (VMSC)-based convolution neural network	Non-Holonomic
Xu Zhang; Jie Yang	2024	An Adaptive Robust EKF Based on Mahalanobis Distance and Non-Holonomic Constraints for Enhancing Vehicle Positioning Accuracy	Non-Holonomic
Hanxu Li, Zihao Liu, Chonghui Li, Yong Zheng, Shuai Tong, Shaojie Chen and Wanxiang Gou	2024	Non-holonomic constraint-assisted GNSS/SINS tight integration navigation method based on a left-invariant extended Kalman filter	Non-Holonomic
Zijian Wang,Jianghua Liu ,Jinguang Jiang ,Jiaji Wu ,Qinghai Wang, Jingnan Liu	2025	An Adaptive Combined Filtering Algorithm for Non-Holonomic Constraints with Time-Varying and Thick-Tailed Measurement Noise	Non-Holonomic

In addition to navigation and localization, robotics is also a major application area for holonomic and non-holonomic constraints. In the design and control of robots, especially mobile robots, the use of constraints is crucial for optimizing movement, path planning, and obstacle avoidance. A detailed overview of constraint applications in the field of robotics is presented in **Table 6** below:

Table 6. Constraint Applications in Robotics

Author(s)	Year	Title	Constraint Type
Jacob J. Johnson, Linjun Li, Fei Liu, Ahmed H. Qureshi, Michael C. Yip	2020	Dynamically Constrained Motion Planning Networks for Non-Holonomic Robots	Non-Holonomic
Mısır, O, & Gökrem, L	2020	Sürü robotları için esnek ve ölçeklenebilir toplanma davranışı metodu	Non-Holonomic
Mohseni Alireza, Duchaine Vincent, Wong Tony	2021	Experimental Study of Path Planning Problem Using EMCOA for a Holonomic Mobile Robot	Holonomic
Riky Tri Yunardi, Deny Arifianto, Farhan Bachtiar, Jihan Intan Prananingrum	2021	Holonomic Implementation of Three-Wheel Omnidirectional Mobile Robot Using DC Motors	Holonomic

Author(s)	Year	Title	Constraint Type
Yayan, U., & Erdoğmuş, A.	2021	Endüstriyel Robot Hareket Planlama Algoritmaları Performans Karşılaştırması	Non-Holonomic
Anupam Choudhary, Yuichi Kobayashi, Francisco J. Arjonilla, Satoshi Nagasaka, Megumu Koike	2021	Evaluation of Mapping and Path Planning for Non-Holonomic Mobile Robot in Narrow Pathway	Non-Holonomic
Stephen I.C. Gulo, Tua A. Tamba	2021	Perancangan Kontrol Pelacakan Lintasan untuk Robot Otonom Beroda Diferensial	Non-Holonomic
Ouach, MK; Eren, T	2021	Mobil Robotların Formasyon Kontrolünde Giriş Kısıtlamaları	Non-Holonomic
Amperawan, A., Andika, D., Anisah, M.,	2022	Sistem Deteksi Posisi dan Pengambilan Bola pada Robot Sepak Bola	Non-Holonomic
Budi Rahmani,Ajib Alfarisi,Ilmi Ilmi,Miftahuddin Miftahuddin,M Agus Wahyudi,Melyana Melyana,Mahrita Mahrita	2023	Real-time Multi-Level Wireless Control Model based on IoT for Wheeled Robots	Holonomic
Harlan Kurnia AR	2023	Pemanfaatan Sensor LDR Pada Robot Light Follower Dengan Konsep Holonomic Sebagai Media Pembelajaran	Holonomic
Murad Bashabsheh	2024	Autonomous Robotic Systems with Artificial Intelligence Technology Using a Deep Q Network-Based Approach for Goal-Oriented 2D Arm Control	Holonomic
Jimmy Wu, William Chong, Robert Holmberg, Aaditya Prasad, Yihuai Gao, Oussama Khatib, Shuran Song, Szymon Rusinkiewicz, Jeannette Bohg	2024	TidyBot++: An Open-Source Holonomic Mobile Manipulator for Robot Learning	Holonomic
Islamiati, F.N.	2024	Trajectory Tracking pada Mobile Robot Non-Holonomic dengan Sliding Mode & Model Predictive Control	Non-Holonomic
Kibar, A.L.I., Gürkal, A.E., Özer, E., İnner, A.B.	2024	Investigation of Deviation in Differential Drive AMR Induced by Caster Wheels	Non-Holonomic

The field of autonomous vehicles is one of the key focuses in the development of modern technology, which heavily relies on the application of both holonomic and non-holonomic constraints. Autonomous vehicles, including smart cars, transport robots, and unmanned combat vehicles, require accurate navigation and motion control systems to operate efficiently in various terrain and environmental conditions. A detailed overview of constraint applications in autonomous vehicles is presented in **Table 7** below:

Tabel 7. Aplikasi Konstraint Bidang Kendaraan Otonom

Author(s)	Year	Title	Constraint Type
Uzun, E, & Bingöl, O	2021	İki tekerlekli denge araçları için geribeslemeli doğrusallaştırma tabanlı denetleyici tasarımı	Holonomic
Atilla Bayram , Mehmet Nuri Almalı , Firas Muhammad Al-naqshbandı	2022	Bir insansız kara aracının model öngörü kontrol metodu ile GPS tabanlı yol takibi	Non-Holonomic
Simbolon, M, Harnyoto, H, & Irawan, D	2022	Analisis Penggunaan Roda Omni pada Kendaraan Tempur ANOA 6x6 Wheel Release Portable	Non-Holonomic
Rohim Aminullah Firdaus, Mohammad Arif Rahmatulloh, Dzulkiflih, Muhimmatul Khoiro	2023	Analisa Lagrange pada Dinamika Stroller Non-Holonomic Berbasis Komputasi Fisika	Non-Holonomic
Kibar, A, Gürkal, AE, Özer, E, & İnner, AB	2024	Diferansiyel sürüşlü otonom mobil robotların avare teker kaynaklı sapmaların incelenmesi	Non-Holonomic
Gülşah Demirhan Aydın; Deren Doğan; Yusuf Tuğberk Türken	2024	Lyapunov-based Controller Design for Precise Monitoring, Speed Control and Trajectory Planning in Autonomous Tractors with Trailers	Non-Holonomic

3.2. Discussion

3.2.1. Distribution of Holonomic and Non-Holonomic Constraints

The results of this systematic literature review reveal that the application of holonomic and non-holonomic constraints in modern technology shows an uneven distribution, with a dominance of non-holonomic constraints. These findings reflect the current research trend, which places more emphasis on dynamic systems with limited degrees of freedom, where non-holonomic models provide greater flexibility and efficiency in technology development, particularly in the fields of robotics and navigation. The distribution of articles based on the type of constraint shows that 24 out of 32 articles discuss non-holonomic constraints, while only 8 articles focus on holonomic constraints. This difference in numbers indicates that the challenges and research opportunities in the non-holonomic domain remain a primary focus for researchers, especially due to the complexity of controlling such systems, which requires more advanced control approaches such as predictive control, motion planning, or machine learning. In terms of application areas, non-holonomic constraints are most commonly applied in navigation technology and mobile robotics systems. This aligns with the characteristics of navigation and moving robots, which often cannot move directly in all directions. For example, a robot with fixed wheels (differential drive) cannot move sideways directly. The implementation of non-holonomic constraints enables the development of more realistic and efficient navigation algorithms in real-world environments.

Meanwhile, holonomic constraints were found more frequently in studies focused on control systems and simulations in structured environments, where all degrees of freedom can be represented independently. Although fewer in number, the role of holonomic constraints remains significant, particularly in the early design of systems and high-precision motion planning. The distribution of journals, not all of which are ranked in high quartiles (Q1 or Q2), indicates that research related to constraints, especially those exploring theoretical and practical integration, is still dispersed across various levels of scientific forums, including conference proceedings. This reflects that research on this topic is still evolving and open to further exploration, including integration with the latest technologies such as autonomous systems, IoT, and artificial intelligence.

3.2.2. Contributions of Holonomic & Non-Holonomic Constraints in Modern Technology

Based on the results obtained from the literature analysis on the application of holonomic and non-holonomic constraints in various fields of technology, it is clear that both types of constraints play a significant role in improving system performance in various modern applications. Holonomic and non-holonomic constraints are crucial in the development of navigation technology, particularly for vehicles and robots operating in dynamic and complex environments. Research by Sun & Yang, (2020) demonstrates how a tight coupling method between BDS PPP and INS based on non-holonomic constraints can reduce position errors, while Zhang & Yang (2024) developed an effective adaptive EKF method to improve vehicle position accuracy. Zhang et al., (2020) highlight the importance of lever arm accuracy in land vehicle navigation. Furthermore, Yang et al., (2021) introduced an adaptive filter based on non-holonomic constraints that enhances the resilience of the navigation system even in the presence of disturbances. On the other hand, Wang et al., (2025) proposed an adaptive filtering algorithm to address measurement disturbances, improving navigation system accuracy in high-noise conditions. Li et al., (2024) introduced GNSS/SINS integration based on an Extended Kalman Filter supporting non-holonomic constraints, enabling high-speed vehicle navigation with higher accuracy. Xiao et al., (2021) utilized a Residual Attention Network to estimate confidence in the GNSS/INS system, introduced GNSS/SINS integration based on an Extended Kalman Filter supporting non-holonomic constraints, enabling high-speed vehicle navigation with higher accuracy. Cheng et al., (2023) shows how the application of non-holonomic constraints can enhance the performance of multi-GNSS

PPP/INS in dense urban environments, while Li et al., (2023) used convolutional neural networks to improve the precision of non-holonomic-based GNSS/SINS.

On the other hand, holonomic constraints also make a significant contribution to enhancing the performance of navigation systems. Yuniawan et al., (2021) developed a holonomic robot navigation system for medical logistics delivery, enabling the robot to move with high flexibility and precision. Imamoglu et al., (2023) compared various local planner algorithms for omnidirectional robots based on ROS, demonstrating how holonomic control facilitates more efficient navigation in complex environments. Overall, the implementation of both holonomic and non-holonomic constraints has a substantial impact on improving the accuracy, resilience, and performance of navigation systems. This enables various applications to operate more efficiently and robustly across diverse environments and conditions.

Furthermore, in the field of robotics, understanding the distinction between holonomic and non-holonomic robots is a key aspect in designing optimal systems. The fundamental principles of robotics encompass mechanical structure, actuation systems, and control strategies, all of which play crucial roles in the development of efficient and effective robots. In terms of navigation and mobility, robots are generally classified into two main categories based on their motion constraints: holonomic and non-holonomic robots. Holonomic robots have the ability to move freely in three dimensions without directional limitations, offering high flexibility in navigation (Alireza et al., 2021). Alireza et al., (2021) conducted an experimental study using the Enhanced Multi-objective Cooperative Optimization Algorithm (EMCOA) for path planning in holonomic mobile robots, demonstrating improvements in navigation efficiency and precision. Supporting this development, Yunardi et al., (2021) designed a three-wheeled omnidirectional robot with DC motors, enabling free-directional movement and flexible navigation. In the area of control, Rahmani et al.,(2023) developed an IoT-based multi-level wireless control model for wheeled robots, allowing for efficient real-time control. Kurnia, (2023) applied the holonomic concept to a light-following robot based on LDR sensors, serving as an educational tool for robotic navigation systems. Furthermore, Wu et al., (2024) introduced TidyBot++, an open-source holonomic manipulator robot designed for efficient household manipulation tasks and applicable in robotics education. Even more, Bashabsheh, (2024) eveloped an autonomous robotic system using a Deep Q-Network (DQN) for goal-oriented control of a two-dimensional robotic arm.

In contrast, non-holonomic robots face specific motion constraints, such as the inability to move directly sideways, which requires more complex path planning and control strategies. Choudhary et al., (2021) evaluated mapping and path planning techniques for non-holonomic robots in narrow corridors, demonstrating the effectiveness of such solutions in confined spaces. Manullang et al., (2020) employed inverse kinematics to control autonomous wheeled robots, enabling precise movement in restricted environments. Significant innovation was also demonstrated by Johnson et al., (2020) through the Dynamic MPNet algorithm, which utilizes neural networks for real-time motion planning in non-holonomic robots. This approach improves data efficiency and model generalization and has been tested in simulations and indoor environments using Dubins robots. Gulo et al., (2021) developed a trajectory tracking control system based on Lyapunov stability analysis for differential wheeled robots, enhancing path-tracking accuracy. In the domain of robot formation control, Ouach & Eren, (2021) emphasized the importance of input constraints in managing the collective motion of mobile robots. Another specific application was proposed by Amperawan et al., (2022), who designed a position detection and ball retrieval system for soccer robots using a combination of compass, camera, encoder, and infrared sensors. Meanwhile, Mısır & Gökrem, (2020) expanded swarm robotics approaches through a flexible and scalable gathering behavior model, improving the efficiency of collective robot coordination.

These advancements align with developments in the field of autonomous vehicles, where the distinct characteristics of holonomic and non-holonomic systems remain crucial factors influencing control system design, path planning, and system stability. In non-holonomic systems, the limitations in degrees of freedom necessitate more complex mathematical approaches and control techniques. Firdaus et al., (2023) utilized the Lagrangian formulation to analyze the dynamics of a stroller as a representation of a non-holonomic system. This computational approach is instrumental in understanding and controlling mechanical systems with constrained motion. Research by Kibar et al., (2024) investigated motion deviation caused by the use of caster wheels in autonomous mobile robots with differential drive, contributing to the development of more accurate and adaptive control design. In the military application domain, Bayram et al.,(2022) analyzed the use of omni-wheels on the ANOA 6x6 combat vehicle. The study evaluated how the wheels affect the maneuverability and stability of the vehicle under various terrain conditions, integrating vehicle design with its motion constraints. Furthermore, Aydın et al., (2024) developed a Lyapunov-based controller for an autonomous tractor with a trailer, significantly improving tracking precision, speed control, and operational path planning efficiency. On the other hand, in holonomic vehicle systems, the freedom of movement becomes a key advantage. Bingöl & Uzun, (2021) designed a linearization feedback controller for a two-wheeled holonomic vehicle. The results showed significant improvements in system stability and control response under dynamically changing environmental conditions.

Although this study has been conducted systematically with the selection of relevant and representative articles, there are several limitations that should be noted. The limited access to high-quality articles and the variation in technical terms used in the literature resulted in the possibility of missing some relevant studies. Additionally, the dominance of research in the fields of robotics and navigation means that the findings in this review may not fully represent the application of holonomic and non-holonomic constraints in other technology sectors such as industrial automation, biotechnology, or medical systems. Nonetheless, the findings from this study provide important implications for the development of modern technological systems, particularly in the design and control of efficient and adaptive dynamic systems. Researchers and practitioners can utilize the understanding of the characteristics of both types of constraints to determine the appropriate approach based on the specific needs of their respective fields. Moreover, further integration with technologies based on artificial intelligence, autonomous systems, and the Internet of Things (IoT) presents significant opportunities for broader, interdisciplinary innovation with impactful outcomes.

4. Conclusion

The distribution of holonomic and non-holonomic constraints in modern technology reveals the dominance of non-holonomic constraints, particularly in the fields of navigation, robotics, and autonomous vehicles. Non-holonomic constraints are more commonly applied in systems with limited degrees of freedom, such as differential drive robots and autonomous vehicles, which require more complex control for path planning and maneuvering. In contrast, holonomic constraints are more prevalent in applications that demand high precision and unrestricted movement, such as omnidirectional robots. Holonomic constraints are typically used in systems operating in structured environments with full degrees of freedom.

Both holonomic and non-holonomic constraints significantly contribute to the efficiency and performance of modern technological systems. Non-holonomic constraints enhance the flexibility, resilience, and efficiency of systems, particularly in robotics and navigation technologies operating in dynamic environments. Systems utilizing non-holonomic constraints are better able to adapt to disturbances and improve accuracy in position determination. On the other hand, holonomic constraints contribute to systems requiring highly precise movement, improving system efficiency with unrestricted motion and more accurate control. Both types of constraints play a crucial role in enhancing the performance and efficiency of modern technological systems, particularly in the development of robotic systems and autonomous vehicles.

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