An In-Depth Analysis of Artificial Intelligence on Service Capabilities of Humanoid Robots

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Abstract

Artificial intelligence (AI) emulates human intelligence in digital devices and machines. A humanoid robot is designed to imitate the look and form of a human body and is primarily used for humanitarian assistance and interaction. AI is applied to humanoid robots to allow intelligent behavior and decision-making, resulting in the ability to execute service activities and achieve goals intelligently in the human-robot interaction environment. The paper is a systematic literature review of studies published in the last four years that presents and assesses how AI techniques and methods have been applied to humanoid robots to implement and enhance service capabilities. The research papers used for the systematic literature review were carefully selected under the directives of the PRISMA method. Eighty studies were screened, and eighteen were used for the review. The results show that the primary AI technique applied in humanoid robots is the Convolutional Neural Network (CNN). The results show that the effective AI techniques used in humanoid robots based on a specific area are Hybrid Convolutional Neural Network (CNN) – Long-Short Term Memory (LSTM), Artificial Neural Network (ANN), Convolutional Neural Network (CNN), Deep Convolutional Neural Network DCNN), Recurrent Neural Network (RNN), and Grow-when-required Network (GWR). The study provides AI techniques and methods utilized in modern studies that can be used as a reference for future studies, research, and innovation.

CCS Concepts

• **Computing methodologies** → Artificial intelligence; Control methods; Robotic planning; Evolutionary robotics.

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Keywords

Artificial Intelligence, Humanoid Robot, Intelligent Behavior, Human-Robot Interaction

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1 Introduction

Humanity in contemporary times is undergoing the Fourth Industrial Revolution which defines the collaboration of the physical, digital, and biological settings. It combines the state-of-the-art developments in Artificial Intelligence (AI), robotics, Internet of Things (IoT), quantum computing, and similar technologies relevant in modern times [1]. The desire to design and create intelligent machines capable of imitating human reasoning, problem-solving, and decision-making ultimately paved the way for AI. AI is a subdiscipline of computer science aimed at producing intelligent machines and devices capable of imitating how humans think and act [2]. AI's core is to fuse human intelligence and self-learning with automation through mathematical techniques, methods, and algorithms [3]. AI introduces Machine Learning, an AI sub-discipline centered on developing algorithms that allow machines to learn and enhance intelligence using gathered data [4]. Among the methods of machine learning is Deep Learning. In Deep Learning, created algorithms for effective learning are based on the human brain and are referred to as neural networks [5]. AI and the mentioned sub-fields are applied in real-life scenarios manifested in intelligent machines that support human activity, such as driverless cars, speech recognition, and intelligent robotics. AI has been utilized in robotics and is responsible for massive developments in mobile robotics and automation [6].

A humanoid robot is designed to imitate the look and form of a human body and human emotion and interaction. Service is the primary purpose of humanoid robots. They automate human tasks and are designed to operate at a professional level. In 2023, the market for humanoid robots is expected to be valued at $3.9

billion [7]. AI-empowered humanoid robots take the roles of personal assistants, physical fitness trainers, and receptionists that enforce human-robot interactions [8]. The applications of AI in humanoid robots refer to intelligent behaviors such as locomotion and smart movement, speech recognition, object recognition, and manipulation, path planning and navigation, responsiveness and conversation capabilities, decision-making, and question answering. Intelligent behaviors define the service capabilities of humanoid robots, that is, the services they can provide based on what they are capable of doing, supported and enforced by AI.

The researches that demonstrate the application of AI in humanoid robots often focus on an isolated function or feature implemented by using AI models and methods in machine learning and deep learning, such as the fusion of intelligent algorithms and neural networks. There is a lack of research discussing AI applications, specifically machine learning and deep learning, to humanoid robots concerning service capabilities, more so at a macro level in the last four years (2018-2022). The systematic literature review conducted by the researchers will provide relevant information concerning the specified topic and AI methods and techniques under machine learning and deep learning, supported by the discussions, experiments, and conclusions provided by the selected researchers. The paper will contribute to filling the gap of the lack of literary resources that discuss the specified topic and provides insights and recommendations on AI methods and techniques that manifest high levels of efficacy and efficiency when used in humanoid robots for service-based purposes on the systematically reviewed studies. The studies used for the systematic literature review discuss AI in humanoid robotics published in the last four years (2018-2022). The systematic literature review tends to the theoretical and aims to answer the question: *What AI methods under the sub-fields of machine learning and deep learning are used for the implementation of intelligent humanoid robots for service, and which among them is the most effective?* It is expected that the paper will discuss and specify the methods and techniques under AI that are prominently used for implementing functional humanoid robots and provide the highest levels of efficacy based on the gathered literature relevant to the systematic literature review.

2 Methodology

The study is a systematic literature review based on the application of AI to the service capabilities of humanoid robots. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses, otherwise known as PRISMA, was utilized to assess and evaluate the literature gathered for the systematic literature review. PRISMA is a method used in systematic review reporting based on verified proof. It introduces a flow diagram that defines the identification, screening, and inclusion process of including and excluding studies used for the systematic literature review [9]. Standardized criteria were designed and established that provided the constraints for the eligibility of a study to be a selected candidate for usage in the systematic literature review. The studies were retrieved from databases, registers, and other sources. Along with the flow diagram introduced by PRISMA was a checklist consisting of 27 items that evaluated the reporting of the segments of introduction, methods, results, and discussions. The checklist and the designed criteria as shown in Table 1 were used as a basis for collecting studies for the systematic literature review. If a study did not meet the standards set by the criteria and the checklist, then the study was excluded from the collection of studies used.

2.1 Collection and Filtering of the Searched Studies

The process of gathering the studies needed for the systematic literature review encompassed the following stages: (1) The researchers selected an online search engine or online database to search for research papers related to the specified topic; (2) The researchers inputted relevant keywords in the search bar of the selected online search engine or online database; (3) The results were filtered according to the date the studies were published where the studies should be published in the last four years (2018-2022); (4) Selected studies were further filtered according to the title and abstract sections; (5) Gathered studies were stored in an online drive; (6) Gathered studies were further filtered according to their relevance to the specified topic and research question established for the systematic literature review; (7) The final studies used for the systematic literature review were stored in an online drive. Table 2 presents the online tools used for searching studies relevant to the specified topic of the systematic literature review, as well as the number of results produced.

2.2 Search Process and Study Evaluation using PRISMA Flow Model

The PRISMA method introduces the PRISMA flow model, which defines the different stages of the search process and the inclusion and exclusion of literature for the systematic literature review. It provides a clear representation of data referring to the number of research papers and reports identified, screened, assessed, and included, as well as those removed and excluded from the systematic literature review [11]. Figure 1 presents the information flow of the search process and evaluation of research papers used for the systematic literature review. A total of 18 studies were verified eligible and marked as the official studies used for the literature review.

3 Results and discussion

The researchers conducted a systematic literature review to identify the applications of AI in humanoid robots. The following section details and discusses the results gathered by the researchers after reviewing collected studies that underwent a searching and screening process to enforce user eligibility.

3.1 Search Process and Study Evaluation Results

A total of 80 research papers were searched and collected by the researchers. The researchers conducted a screening process to determine which research papers were eligible for use in the systematic literature review. Using the PRISMA method, 18 research papers were verified to be eligible under the constraints of the specified criteria (Table 1), where 13 studies were collected from online databases, and 5 studies were collected from online search engines (Figure 1). The eligible studies were published within the last four

Table 1: Standard Criteria for Qualified Studies

Specified Criteria	Description
AI Area Focused by the Study	AI in Robotics
Specific Topic in Selected AI Area of the Study	Application of AI, machine learning, and deep learning in humanoid robots for service
Year of Publishing of the Study	Years 2018 - 2022
Number of Studies to be Collected	Each researcher must collect 20 published research papers
Number of Pages of the Study	Must be at least ten (10) pages including references
Type of Research Method of the Study	Must be quantitative research

Table 2: Online Tools and Search Results

Online Tool Title	Link	Category	Language	Results
Emerald	https://www.emeraldgrouppublishing.com/	Online Database	English	248
Frontiers	https://www.frontiersin.org/	Online Database	English	5221
Google Scholar	https://scholar.google.com/	Online Search Engine	English	17000
IEEE Access	https://ieeeaccess.ieee.org/	Online Database	English	55
IEEE Xplore	https://ieeexplore.ieee.org/Xplore/home.jsp	Online Database	English	255
MDPI	https://www.mdpi.com/	Online Database	English	2
Mapua Library One Search	https://library.mapua.edu.ph/	Online Search Engine	English	31
ResearchGate	https://www.researchgate.net/	Online Database	English	Data Undefined
ScienceDirect	https://www.sciencedirect.com/	Online Database	English	536
Sensors	https://www.mdpi.com/journal/sensors	Online Database	English	55
SpringerOpen	https://www.springeropen.com/	Online Database	English	24
Taylor&Francis Online	https://www.tandfonline.com/	Online Database	English	206
UMP	https://journal.ump.edu.my/	Online Database	English	14
Wiley	https://onlinelibrary.wiley.com/	Online Database	English	234

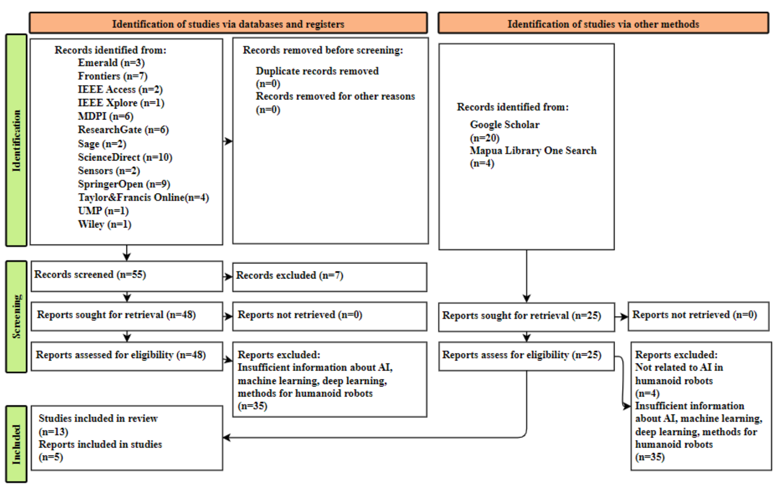

Figure 1: PRISMA Flow Diagram of Search Process and Evaluation of Studies for Review

years (2018-2022). Three (3) studies with reference number [15], [16], and [24] were published in 2018. Two (2) studies with reference numbers [18] and [22] were published in 2019. Two (2) studies with reference numbers [13] and [21] were published in 2020. Five (5) studies with reference number [12], [20], [23], [25], and [29] were published in 2021. Three (3) studies with reference numbers [17], [26], and [28] were published in 2022. Table 3 summarizes the eligible studies utilized for the systematic literature review.

Table 3: Summary of Eligible Studies Used for Review

Objective and Methodology	Results and Conclusion
Identifying and analyzing strategies based on neural network methods and other artificial intelligence techniques and develop a Neural Network technique that allows the untroubled movement, path planning, and navigation of a humanoid robot ROBONOVA-1 in an obstacle prone environment [12]. Quantitative, experimental, and observational. Simulations were carried out, and the results were compared to the actual experiments. ROBONOVA-1 was programmed with the proposed novel Neural Network technique based on multiple Artificial Intelligence techniques. Techniques include Fuzzy Reactive, CS, ANFIS, Neuro-Fuzzy, IWO, Swarm Optimization, Adaptive Fuzzy, MLP, Genetic Algorithm, Bat Algorithm, MANFIS controller, and others.	ROBONOVA-1 successfully navigated around the arena in simulations and actual experiments, reaching the specified destination from the predefined position amid obstacles. The deviation for path length between simulation and experimental results was within 6%. The deviation for the time taken for ROBONOVA-1 to get to the specified destination between simulation and experimental results was within 6%. The proposed novel Neural Network technique based on multiple Artificial intelligence techniques for path planning and navigation successfully allowed ROBONOVA-1 to traverse the obstacle-prone environment and arrive at the specified destination effectively. The proposed technique is verified to be effective and functional by simulation and experimental methods carried out.
Description, development, and implementation of a neuroanatomic grounded spiking neural network with word learning capability for object naming and visual attention of iCub humanoid robot [13]. The experimental platform encompassed tests with a simulated and actual iCub humanoid robot. iCub simulator was used for the simulated method. The spiking neuron network model was used for object naming and visual attention capabilities of the iCub humanoid robot.	In both visual and auditory modes, the iCub humanoid robot with a neuroanatomic grounded spiking neural network could learn to associate labels with the object, separating the horizontal and vertical objects, where tests with vertical objects presented more significant spikes and weight than horizontal objects. Objects were moved to different locations. iCub humanoid robot could recall the correct label of the object in all ten tests. Neuroanatomic grounded spiking neural networks can be integrated with humanoid robotics for object naming and visual attention. Preferred orientations cause increases in V4, FST, and STP sectors. Learning object's label happens in STP and PB sectors through STDP. Object name learning requires visual attention. After successful training using biologically-based learning, presenting only visual input to the iCub humanoid robot results in completing auditory sectors of object labeling and recalling.
Development and implementation of a navigational controller for effective path planning of a NAO humanoid robot based on Artificial Neural Network (ANN) [14]. Quantitative, experimental, and observational. Artificial Neural Network (ANN) was applied to the NAO humanoid robot for navigation and path planning testing. An experimental platform for testing NAO humanoid robot path-planning and navigation was designed under laboratory conditions.	NAO humanoid robot implemented with Artificial Neural Network (ANN) successfully generated a practical path to reach the destination amid multiple obstacles. The average percentage of error in path length generated by the NAO humanoid robot between the simulation and experimental platform within five tests was 6.29. The average percentage of error in time taken for the NAO humanoid robot to reach the specified destination was 4.56. Simulation results show lower values compared to experimental results due to factors such as robot foot slippage, loss in data transmission, and others present in the experimental platform. Artificial Neural Network (ANN) is verified to be more efficient and optimal in implementing path-planning and navigation of the NAO humanoid robot compared to other intelligent approaches and classical methods. NAO humanoid robot successfully generated an optimal path within the obstacle-prone and cluttered environment. Effective and optimized path planning and navigation within a humanoid robot can be achieved and implemented through an Artificial Neural Network (ANN).

Develop and apply a 4-stage emotional analysis algorithm to NAO humanoid robot to learn and recognize emotions using an artificial neural network (ANN) [15]. Experimental methodology. The proposed Emotion Analysis Algorithm is implemented. The image is taken by the camera of the NAO humanoid robot. The Viola-Jones algorithm is used for face detection. The detected face is measured for distances using the Geometric Based Facial Distance Measurement Technique. The Facial Action Coding System (FACS) determines the movements of facial muscles. Artificial Neural Network (ANN) is used to classify movements into emotions.	The proposed Emotion Analysis Algorithm with Artificial Neural Network (ANN) allows the NAO humanoid robot to detect emotions effectively. Through the application Choregraphe and python, the NAO humanoid robot successfully identified emotion. Results from the interaction are printed and enforce dialogue. NAO humanoid robot successfully identified the emotion of a real human test subject and extended interaction. The proposed Emotion Analysis Algorithm encompassing Viola-Jones Algorithm, Geometric Based Facial Distance Measurement Technique, FACS Technique, and Artificial Neural Network (ANN) can be implemented and used for effective emotional detection and recognition with all humanoid robots.
Proposal of a unified framework encompassing navigational scenarios, machine learning algorithms, hierarchical automata, and error recovery methods for opening and navigating doors by human support and service robots [16]. Evaluation of unified framework using two designed experimental platforms for validation of the unified framework's robustness and standard of door opening procedure. The framework was implemented in Toyota Human Support Robot (HSR) and tested. "Help Me Carry Task" was used to validate the door opening procedure	The Toyota Human Support Robot (HSR) achieved a 95% success rate in the "Help Me Carry Task" performed fifty times. Handle grasping achieved a 98% success rate when encountering non-slippery handles and a 94% success rate for slipper handles. The inability of HSR to open doors depended on door handle type and not HSR's grasping ability. Experimental results verify the robustness and flexibility of the proposed unified framework supported by machine learning algorithms, hierarchical automata, and error recovery methods for door opening and navigation of service robots. The unified framework can be implemented to any standard service robot provided it possesses certain HSR characteristics.
Proposal and development of emotion detection and recognition method for a humanoid robot using Convolutional Neural Network (CNN) and Long Short-Term Memory Network (LSTM) [17]. Experimental setup using Harley humanoid robot. Leave-one-out cross-validation is used to verify the effectiveness of varying models. The model that learns the correlation of image sequences of human expressions and assigned labels is created by combining Convolutional Neural Network (CNN) and Long Short-Term Memory Network (LSTM).	Harley humanoid robot implemented with emotion detection and recognition model using Convolutional Neural Network (CNN) and Long Short-Term Memory Network (LSTM) optimally recognizes emotion in both experimental setups using CK+ database and with real human test subject as long as vision information is abundant. It provides a sub-optimal approach to emotion recognition when facing scenarios of unabundant data. Emotion detection and recognition model based on Convolutional Neural Network (CNN) and Long Short-Term Memory Network (LSTM) effectively utilizes the advantages of deep neural network. The leave-one-out cross-validation method concludes improvement in emotion detection and recognition of the Harley humanoid robot using the proposed model and verifies feasibility and practicability.
Development and proposal of Deep Convolutional Neural Network Technique (DCNN) that provides and enhances Human Support Robot's (HSR) capability of cleaning and inspecting tables operating in a food court environment [18]. The proposed litter detection and cleaning technique and framework encompass a litter detection framework predicated on Deep Convolutional Neural Network Technique (DCNN) and planner module. Toyota Human Support Robot (HSR) was used for the experimental setup. Execution of experimental setup areas characterized by algorithm configuration, preparation and validation of training data, and evaluation and inspection.	Detection of solid food litter achieved a 97% or more confidence level. Detection of liquid food litter and stains achieved 96% or more confidence level. The miss rate garnered 3%, and the false rate garnered 2% for food litter. The planner module takes 0.0145 seconds for path planning and 210.5 seconds for motion planning. The proposed litter detection and cleaning technique and framework using Deep Learning Technique are verified to be highly effective, efficient, and accurate in comparison to existing methods through the experimental results. The method is versatile and improves the current state of service robots in the cleaning sector.

Developing and implementing a self-learning Humanoid Robot with question answering system using a Deep Learning approach and Big Data [19]. An experimental platform was designed. Model testing was done using Recurrent Neural Network (RNN) and Convolutional Neural Network (CNN) based encoders. Big Data analytical tools utilized Google BERT. Comparison and evaluation were carried out using the results of RNN and CNN-based encoders.	The RNN-based encoder performs better with an Exact Match Score (EM Score) of 68.87/82.43 compared to the CNN-based encoder's Exact Match Score (EM Score) of 53.99/69.55. The Google BERT model garnered a higher F1 score than the proposed model. The proposed model effectively implements the question-answering system of the humanoid robot. The proposed self-learning humanoid robot model effectively implemented the question and answer system using the Recurrent Neural Network (RNN) Deep Learning method and Big Data systems. Recurrent Neural Network (RNN) based encoder and BiDAF attention layer garnered better Exact Match Scores and F1 Scores which verifies the superiority of the specified Deep Learning Method.
To look at acceptable humanoid service robot implementation models and examples in China, Japan, Korea, and Germany through ethical governance and legal privacy. To study and learn about the consumer maturity model, existing and traditional hospitality operations, and potential AI advancements [20].The Institute's goals are primarily focused on leveraging robot-related technology to enhance and improve the traditional hotels' current business model. In addition, the ethical oversight and legal protection of privacy associated with cutting-edge technology used in the service sector are the assurances that technology will continue to function in the future.	The conventional hospitality business confronts issues with low staff quality, challenging human resource management, and a lack of multilingual competence among employees to serve consumers in other nations, as can be shown by looking into a huge number of books and instances. According to the conclusions obtained in this section, service robots in the hotel industry should concentrate on four areas: user-robot interface, artificial intelligence-based service models, user data protection, and responsibility distribution for robot management.
Develop an intelligent humanoid robot that acts as assistant support for fitness and exercise and implements learning using Grow-When-Required Network (GWR) [21]. Utilizing a created synthetic data methodology and novel exercise dataset supported by Virtual-Squat dataset. Evaluation of Gamma-GWR motion prediction capabilities was carried out in the initial experiment. The secondary experiment relied on a comparison between Gamma-GWR and Subnode-GWR.	Gamma-GWR is unable to predict upward motion. Subnode-GWR performs effectively but relies on a continual learning scheme. Reduced accuracy of exercise is observed in Subnode-GWR continual learning scheme. Accuracy for joints over exercise garnered an average accuracy of 88%, which validates the robustness of Subnode-GWR. The designed system for the humanoid exercise robot operates effectively in terms of its purpose but manifests limitations. Subnode-GWR expands network capacity to solve catastrophic forgetting, which causes limitations in the Grow-When-Required Network. Subnode-GWR needs supported input from a supervisor in the learning period.
Exploring Human Activity Recognition (HAR) system enabled by Artificial Intelligence and Machine Learning techniques for predicting human activities [22]. The experimental platform uses datasets and simulations. UCI opportunity HAR dataset and UCI HAR using smartphone datasets were processed and utilized for testing. Machine learning models utilized encompassed Decision Tree, Random Forest, Support Vector Classifier, K-Nearest Neighbor, and Deep Neural Network. Measurement tools used encompassed accuracy, precision, recall, and F1 measure.	HAR in the opportunity UCI dataset attained a better average F1 score than the UCI HAR dataset. Improved performance in activity recognition is manifested by models using the opportunity HCI dataset in comparison to the UCI HAR dataset. UCI dataset is the optimal dataset under the terms of feature extraction for recognizing human activity. The support vector classifier attained the highest test accuracy, while the designed custom deep neural network was the most consistent. The optimal machine learning algorithm for human activity recognition and task execution of humanoid robots is Neural Network due to its immense flexibility.
Development and implementation of novel models based on Deep Learning's Convolutional Neural Network (CNN) and Long Short-Term Memory (LSTM) for imitation and learning of object manipulation behavior of Robotis-Op3 humanoid robot [23]. Six designed Convolutional Neural Networks (CNN) and combined CNN-LSTM models are utilized for object manipulation learning on Robotis-Op3 humanoid robot enforced by the LfD teleoperation method. Experimental platforms were designed for testing. Models were trained with Adam Method and embedded into the Robotis-Op humanoid robot.	CNN models produced fewer losses in training and validation. CNN-LSTM hybrid models produced fewer losses in terms of validation and training and less risk of overfitting. CNN models produced low losses in training and validation. CNN-LSTM hybrid models provide better and more efficient results compared to CNN models and attain low levels of deviation in estimation. The proposed CNN and hybrid CNN-LSTM models successfully estimate nonlinear attributes of object manipulation. Hybrid CNN-LSTM models achieved improved approximation values and better accuracy during the testing segment and effectively learned the required joint positions garnering 0.001 and 0.002 MSE losses.

By offering organized data about humanoid robot heads on essential topics, including design and control, this study seeks to advance research into humanoid robotics. To provide historical context and make it possible to identify potential future directions, this gives a chronological examination of the overall evolution of humanoid robot heads [24]. We attempted to review most of the information found in the literature by consulting hundreds of scientific publications and concentrating on the major academic publishers. We were interested in learning what constitutes and what characteristics a humanoid robot head has.	The findings show that an android face is perceived as more recognizable and human. In a different study, 48 humanoid robot images were scored on a scale of 1 to 5, with one being the least humanlike and five being the most. The study shows that a humanoid robot head's perceived humanness is enhanced by its increased head breadth and several facial features (brow line, eyes, mouth, nose, etc.; see Romeo in Fig. 1 and robot heads in Fig. 2). The thesis made by the authors is supported by previous studies, although they also note that behavior might also be to blame for people's acceptance of robots. They suggested that a humanoid robot head be defined as one that is made to be integrated into a humanoid robot, has at least one guiding sense, and evokes humanlike physical qualities. We concentrated our research on currently available robot heads that matched these specifications. The history of humanoid robot heads has been reviewed in general. In general, these robot heads are made up of various sensing components, including artificial vestibular-ocular systems, hearing, and vision.
Development and implementation of object recognition using a palm-size tactile sensor array and Deep Convolutional Neural Networks (DCNN) for humanoid robots [25]. An experimental setup was designed for testing. Tactile images were tested using a recognition system and resolution supported by bicup interpolation method. The designed recognition algorithm is evaluated and tested by utilizing transfer learning DCNN. Comparison of nineteen models enhanced with the multimodal approach.	The humanoid robot attained a recognition rate of 76.55% while utilizing the AlexNet DCNN classifier. Image size of the tactile image increased by two times after resolution enhancement by bicubic interpolation resulting in an increased recognition rate of 4.14%. Resolution enhancement implementation produced an increased recognition rate of 7.77%. InceptionResNetV2 produced a recognition rate of 91.86% and 11.23 seconds of training time, validating itself as the best-performing DCNN method for object recognition. The recognition rate increased by 0.87% after applying multimodal learning. InceptionResNetV2 successfully and effectively maximized the recognition rate due to its attained rate of 91.82%, further optimized by the recognition rate and training time under the maximum efficiency base attained. The developed palm-size tactile sensor array successfully allowed effective object recognition using InceptionResNetV2 multimodal learning models within a humanoid robot.
Design and implement a system capable of carrying out physical therapy for rehabilitation implemented using the NAO humanoid robot with Artificial Intelligence and Deep Learning methods [26]. Experimental through testing rehabilitation system prototype that consists of text-to-speech enhancement, Google speech API, human pose and open pose estimation and model selection through Neural Networks, sensory input and output, and logical analysis through computer simulation. Test cases and logical calculations for posture were utilized.	The machine learning model successfully established a connection with the NAO humanoid robot. The robot implemented Google Speech API for text-to-speech and speech-to-text capabilities. Implementation of the OpenPose model for executing the T exercise was effective and scalable. The designed system provided proof-of-concept and emphasized on implementation of image analysis using present models. The application and execution of the designed system using python 2.7 successfully demonstrated the capabilities of a physical therapist humanoid robot.
Identifying and implementing a model based on Generative Pre-trained Transformer (GPT) language models for successful natural language processing (NLP) using NLP cloud-based services and the Internet of Things to transform humanoid robots into teachers [27]. Experimental setup encompassing deployment of model for text generation. IBM Watson Assistant executed question-and-answer capabilities and was used for text-to-speech conversion. Natural language processing was carried out through GPT-J-6B, which divides the text into tokens to identify the context. Evaluation of software and analogical application for NLP services of NLPcloud. The model was tested through question-answering, summarizing, and sentiment analysis.	The proposed model software executes successfully. Cloud-based service generates -100ms latency, which transcends what is expected. Sentiment outcomes provided through a label and score can be directed to and played by the humanoid robot. Response of GPT-J for question and answer capability is normal if temperature and Top-P are zero. The response becomes unexpected and unusual if temperature and Top-P have high values. Text generation can be optimally and generally performed by GPT-J under the constraints of GPT-J parameters and the quality of questions asked. GPT language models encompassing APIs, programmable robots, and intelligent sensors for natural language processing (NLP) related purposes are environments that allow standard implementation of the proposed model.

This mobile robot's purpose is to give the user simple home help. To gain access to the connection interface, which increases the camera sensor's visible field of view. To focus their research on how people interact with machines by developing companion robots with animal- or humanoid-like designs [28].
The three service tasks that Marvin was designed to provide include monitoring the elderly and those with decreased mobility, distant availability and connectivity, and night help. The researchers suggest a much smaller omnidirectional platform than prior efforts, allowing for dynamic motion and efficient obstacle avoidance.
To evaluate football's functional training. To boost the efficiency of smart football training. To analyze the players' functional training with the goal of enhancing football robot-detecting technology [29].
As a result of the need for AI within practical training of football players engage in linguistic extraction and action recognition. Based on deep learning (DL) and information linked to human action recognition, the enhancement of athletes' speed and strength in functional training is investigated.

Future research will aim to broaden the usability of Marvin to previously unrecognized service robots' tasks while also attempting to enhance experimentation by delivering more task-specific experimental outcomes. More specifically, Marvin's use of person-centered advanced automation tasks will receive a lot of attention.
Service robotics is recalling expanding marketplaces, industries, and scholars' interests. Their use in the caregiving industry might ease the burden on assistive operators by offering basic help that doesn't need a lot of dexterity or adaptability.

Due to the FCN model's poor feature extraction capabilities, it is simple for the other non-site line objects to interact with field line recognition, which leads to inaccurate detection findings.
The outcomes demonstrate the viability of the intelligent training system and the high-field detecting precision of the developed football robot. The study serves as a guide to producing football robots and intelligent training programs for athletes.

3.2 Artificial Intelligence in Humanoid Robots

Humanoid robots are primarily used to serve human needs in various fields. Development in intelligent behavior in humanoid robots continues to accelerate to achieve autonomous humanoid robots capable of imitating human action and decision-making. Through artificial intelligence, learning is enforced in humanoid robots, which provides a foundation for the addition and enhancement of various abilities that humans possess. A general overview of the areas where artificial intelligence is applied in humanoid robots is presented in Figure 2.

Specific AI techniques and methods utilized in humanoid robots were identified. The techniques and methods identified and collected were under machine learning and deep learning. The techniques and methods were used to implement the various areas specified in Figure 2. Machine learning techniques and methods primarily encompassed algorithms, while deep learning techniques and methods encompassed primarily neural networks. The specified areas define the service capabilities of a humanoid robot supported by intelligent behavior. Figure 3 provides a general rundown of the AI techniques and methods used in humanoid robots.

3.3 Machine Learning and Deep Learning Applications in Humanoid Robots

AI encompasses Machine Learning. Machine Learning produces intelligent machines using collected data to identify patterns and create intelligent decisions, mimicking human intelligence. Machine learning encompasses Deep Learning. Deep Learning utilizes neural networks. Neural networks are artificial imitations of the human brain and are composed of layers that process data and enforce learning.

Figure 4 presents the machine learning and deep learning techniques and methods used in humanoid robots based on the specified capability. Sixteen (16) varying AI techniques and methods under machine learning and deep learning were used in humanoid robots. Convolutional Neural Network is used in six (6) out of ten (10) specified capabilities encompassing the following: Facial and emotional recognition; Visual attention and object detection; Object manipulation; Question answering; Human activity recognition; Natural language processing.

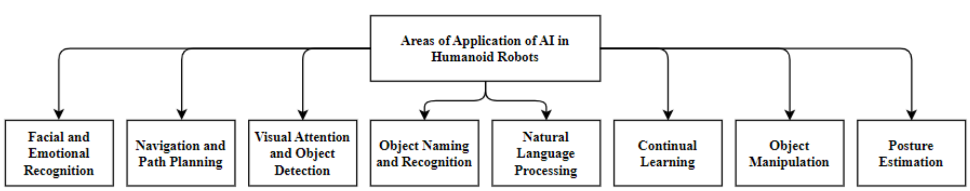

Figure 2: Schematic Representation of the Areas where AI is Applied in Humanoid Robots

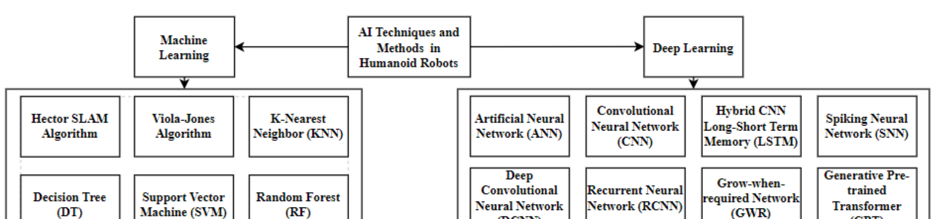

Figure 3: Schematic Representation of the AI Techniques and Methods used in Humanoid Robots

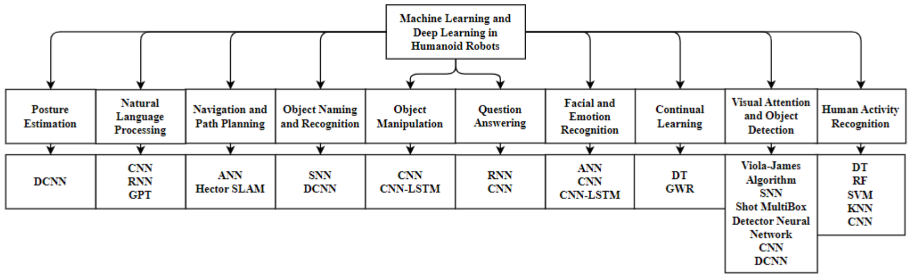

Figure 4: Machine Learning and Deep Learning used in AI Application Areas of Humanoid Robots

3.4 Facial and Emotional Recognition & Navigation and Path Planning

Facial and emotional recognition establishes human-robot interaction. Establishing intelligent behavior for humanoid robots entailing facial and emotional recognition expands humanoid robots' service capabilities, ranging from basic human interaction, assessments and analysis, and human-robot comfort. Three (3) AI techniques were identified for implementing facial and emotional recognition in humanoid robots, namely Artificial Neural Network (ANN), Convolutional Neural Network (CNN), Hybrid Convolutional Neural Network (CNN) – Long-Short Term Memory (LSTM). CNN is effective in handling static recognition, while LSTM is effective in handling dynamic recognition. A hybrid CNN – LSTM technique provides high levels of success rates in facial and emotional recognition [17].

Humanoid robots mimic human locomotion, ensuring effective movement from one place to another. Navigation and path planning ensures humanoid robots intelligently recognize and learn from their surroundings to avoid obstacles. Proper navigation and path planning establishes the efficacy and efficiency of humanoid robots in providing services that require movement and transportation. Two (2) AI techniques were identified for implementing navigation and path planning in humanoid robots: Artificial Neural Network (ANN) and Hector SLAM algorithm. ANN allows humanoid robots to effectively derive a path amid an obstacle-filled environment with minimum error rates and provides an optimal solution for navigation and path planning [12].

3.5 Visual Attention and Object Detection & Object Naming and Recognition

Visual attention and object detection allow humanoid robots to systematically view their environment and is a primary basis for intelligent decisions. Visual attention and object detection expands humanoid robot service capabilities, such as unusual item detection for security, and enforces the imitation of human vision. Five (5) AI techniques were identified for implementing visual attention and object detection, namely Viola-Jones Algorithm, Spiking Neural Network (SNNN), Shot MultiBox Detector Neural Network, Convolutional Neural Network CNN, and Deep Convolutional Neural Network (DCNN). Through CNN's ability to distinguish objects with minimal data, visual attention and object detection are implemented effectively and efficiently with minimal error [18].

Object naming and recognition establish essential learning for humanoid robots. Object naming and recognition allow humanoid robots to distinguish varying objects correctly. Two (2) techniques were identified, namely Spiking Neural Network (SNN) and Deep Convolutional Neural Network (DCNN). Utilizing DCNN offers higher accuracy despite requiring fewer data than other techniques ensuring an optimal and effective solution to object naming and recognition [25].

3.6 Object Manipulation & Question Answering

Object manipulation in humanoid robots allows flexible utilization of objects necessary for any specified purpose. Object manipulation allows humanoid robots to carry out various services, such as carriage and delivery operations. Two (2) techniques were identified for object manipulation, namely Convolutional Neural Network (CNN) and Hybrid Convolutional Neural Networks (CNN) – Long-Short Term Memory (LSTM). Hybrid CNN-LSTM provides maximum functionality that expands on specific scenarios and environments because it accomplishes manipulation with minimal error and noise [23].

Question answering capabilities in humanoid robots enhance human-robot interaction by establishing and supporting conversation capabilities and intellectual behavior that mimic human interaction and decision-making. Two (2) techniques were identified for question answering, namely Recurrent Neural Network (RNN) and Convolutional Neural Network (CNN). RNN supported by BiDAF provides a more efficient flow and operation for question answering in humanoid robots compared to CNN, validated by an 82.43% mark in F1 [19].

3.7 Human Activity Recognition & Continual Learning

Human activity recognition allows humanoid robots to identify enforced human activity and generate decisions based on data retrieved. Applications of human activity recognition for service include physical therapy operations and fitness exercise monitoring. Five (5) techniques were identified, namely Decision Tree (DT), Random Forest (RF), Support Vector Classifier (SVM), K-Nearest Neighbor (KNN), and Convolutional Neural Network (CNN). CNN provides the most effective and accurate results due to various layers of minimal neurons capable of perceiving and assessing human activity based on vision [22].

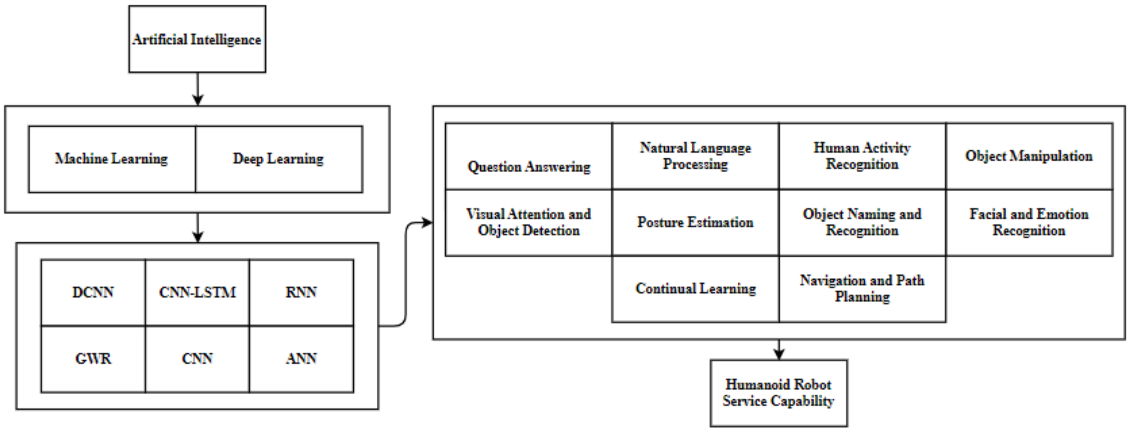

Figure 5: Conceptual Framework

Continual Learning defines effective learning for humanoid robots based on collected input. Intelligent behavior for humanoid robots is structured, trained, and enforced through continual learning generating a humanoid capable of optimal autonomous decision-making. Two (2) techniques for continual learning were identified: Decision Tree Classification Algorithm and Grow-when-required Network (GWR). GWR allows network expansion, which is effective for continual learning and training for intelligent decision-making. Every data collected is directly stored in the GWR ensuring distinct feedback for every input [21].

3.8 Natural Language Processing & Posture Estimation

Natural Language Processing (NLP) for humanoid robots supports human-robot interaction and enforces effective communication. NLP allows humanoid robots to scan and understand text, accept speech as input through auditory means, and accurately interpret input based on various contexts of human language. Three techniques were identified for NLP, namely Convolutional Neural Network (CNN), Recurrent Neural Network (RNN), and Generative Pre-Trained Transformer (GPT). RNN provides accuracy and efficiency in implementing NLP, including speech recognition, language formation, and generalization, and prediction, which is essential for understanding context within human language [26].

Posture estimation supports body part recognition of humans. Humanoid robots with implemented posture estimation capabilities can take the role of essential service personnel such as physical therapists and fitness or exercise coaches. One (1) technique is identified for posture estimation, which is Deep Convolutional Neural Network (DCNN). DCNN allows the prediction of various body parts through regression, providing effective training [26].

4 CONCEPTUAL FRAMEWORK

The systematic literature review tackled the applications of AI in humanoid robots for service. It provided insights into what AI techniques and methods are implemented in humanoid robots and which among them possess the highest efficacy.

Figure 5 presents the conceptual framework of the Systematic Literature Review. AI is identified as the independent variable which encompasses the subsets of machine learning and deep learning, as well as the techniques and methods designed under them identified to be the most effective techniques or methods applied in humanoid robots based on the systematic literature review conducted. The areas of AI applications are the dependent variables encompassing the following: Facial and emotional recognition; Object manipulation; Navigation and path planning; Question answering; Visual attention and object detection; Human activity recognition; Object naming and recognition; Continual learning; Natural language processing; Posture estimation. The quality of the specified areas of AI applications in humanoid robots depends on the implemented machine learning and deep learning technique. The specified areas of AI applications in humanoid robots define the service capabilities of humanoid robots, their efficacy, and functionality level.

5 IMPLICATION AND CONCLUSION

The conducted systematic literature review tends to the theoretical and successfully determined the Artificial Intelligence (AI) techniques, specifically machine learning and deep learning techniques, applied in humanoid robots based on the studies published in the last four (4) years (2018-2022). The systematic literature review also determined the areas of AI applications in humanoid robots, the most common AI technique used for humanoid robots in general, and the most effective AI technique used for each specific area of AI applications. The systematic literature review was conducted by screening an initial number of eighty (80) research papers and filtering the research papers based on the stand criteria set forth and the relevance of the research paper to AI applications in humanoid robots. The extensive screening and filtering process produced eighteen (18) research papers verified as eligible because the papers met the standard criteria and were relevant to the study's topic. The application of AI techniques and methods in humanoid robots is directed toward the service capabilities of humanoid robots. The systematic literature review results show that the primary AI technique applied in humanoid robots based on the identified areas of

AI application in humanoid robots is Convolutional Neural Network (CNN). Furthermore, the results show the most effective AI techniques used in each specific area of AI application in humanoid robots, which encompass the following: Hybrid Convolutional Neural Networks (CNN) – Long-Short Term Memory (LSTM) for facial and emotional recognition; Artificial Neural Network (ANN) for navigation and path planning; Convolutional Neural Network (CNN) for visual attention and object detection; Deep Convolutional Neural Network (DCNN) for object naming and recognition; Hybrid CNN-LSTM for object manipulation; Recurrent Neural Network (RNN) for question answering; CNN for human activity recognition; Grow-when-required Network for continual learning; RNN for natural language processing; DCNN for posture estimation. The results and findings presented in the study contributes to the field of AI and can be used by researchers and other individuals as a reference for studies, research, and innovation that focus on the application of AI, machine learning, and deep learning in humanoid robots.

6 LIMITATION AND FUTURE RESEARCH

The researchers faced limitations while conducting the systematic literature review. The systematic literature review only encompassed research papers. Books and other forms of publications that differ from research papers were excluded. Due to the considerable number of closed-access research papers published online, where access to the research paper required payment, the researchers consumed a large portion of time searching for open-access research papers online relevant to the study. The researchers were limited to time constraints in conducting the systematic literature review. The researchers recommend the further identification, evaluation, and analysis of modern AI techniques and methods used in humanoid robots and extend the scope to cyber security for defense services and sentience to generate and provide more resources and references that can be utilized for other studies, research, and innovation.

References

[1] McGinnis Director. 2022. What is the Fourth Industrial Revolution? (October 2022). https://www.salesforce.com/blog/what-is-the-fourth-industrial-revolution-4ir/
[2] Jake Frankenfield. 2022. Artificial Intelligence: What it is and how it is used. (July 2022). https://www.investopedia.com/terms/a/artificial-intelligence-ai.asp
[3] Rockwell Anyoha. 2017. The History of Artificial Intelligence. (August 2017). https://sitn.hms.harvard.edu/flash/2017/history-artificial-intelligence/
[4] Rice University Department of Computer Science. 2021. Computer Science vs Artificial Intelligence / Machine Learning: What's the Difference? (November 2021). https://csweb.rice.edu/academics/graduate-programs/online-mcs/blog/computer-science-vs-artificial-intelligence-and-machine-learning#:$\sim$:text$=$What%20is%20Artificial%20Intelligence%3F,scale%2C%20in%20a%20replicable%20manner.
[5] IBM Cloud Education. 2020. Deep Learning. (May 2020). https://www.ibm.com/cloud/learn/deep-learning
[6] Robotnik. 2022. Use and applications of Artificial Intelligence in robotics. (April 2022). https://robotnik.eu/introduction-to-robotics-and-artificial-intelligence/#:$\sim$:text$=$AI%20is%20one%20of%20the,or%20tasks%20given%20to%20them
[7] Automate. 2022. Humanoid Robots. (2022). https://www.automate.org/a3-content/service-robots-humanoid-robots
[8] Sanjit Singh Dang. 2019. Artificial Intelligence in Humanoid Robots. (February 2019). https://www.forbes.com/sites/cognitiveworld/2019/02/25/artificial-intelligence-in-humanoid-robots/?sh$=$724e443b24c7
[9] University of Guelph-Humber. 2021. Systematic reviews: Prisma Diagram & Checklist. (December 2021). https://guelphhumber.libguides.com/c.php?g$=$213266&p$=$1406923
[10] University of Texas Arlington. 2022. Quantitative and Qualitative Research. (September 2022). https://libguides.uta.edu/quantitative_and_qualitative_research/quant
[11] Prisma. 2021. Transparent Reporting of Systematic Reviews and Meta-Analyses. (2021). http://prisma-statement.org/
[12] Biswajit Sahoo, Dayal R. Parhi, and Priyadarshi Biplab Kumar. 2018. Analysis of Path Planning of Humanoid Robots using Neural Network Methods and Study of Possible use of Other AI Techniques. (March 2018). https://www.researchgate.net/publication/324156660_Analysis_of_Path_Planning_of_Humanoid_Robots_using_Neural_Network_Methods_and_Study_of_Possible_use_of_Other_AI_Techniques
[13] Daniel Hernández García, Samantha Adams, Alex Rast, Thomas Wennekers, Steve Furber, and Angelo Cangelosi. 2018. Visual attention and object naming in humanoid robots using a bio-inspired spiking neural network. (March 2018). https://www.sciencedirect.com/science/article/pii/S0921889017302439
[14] Asita Kumar Rath, Harish Chandra Das, and Priyadarshi Biplab Kumar. 2018. Application of artificial neural network for control and navigation of humanoid robot. (June 2018). https://www.researchgate.net/publication/326575523_Application_of_artificial_neural_network_for_control_and_navigation_of_humanoid_robot
[15] Fatma Göngör and Onder Tutsoy. 2018. Humanoid Robots Learn and Recognize Seven Facial Emotions with Ann. (December 2018). https://www.researchgate.net/publication/329557920_Humanoid_Robots_Learn_and_Recognize_Seven_Facial_Emotions_with_ANN
[16] Francesco Savarese, Antonio Tejero-de-Pablos, Stefano Quer, and Tatsuya Harada. 2019. Detecting, Opening and Navigating through Doors: A Unified Framework for Human Service Robots. In Proceedings of the 14th International Conference on Software Technologies (ICSOFT 2019). SCITEPRESS - Science and Technology Publications, Lda, Setubal, PRT, 416–427. https://doi.org/10.5220/0007947604160427
[17] Tzuu-Hseng S. Li, Ping-Huan Kuo, Ting-Nan Tsai, and Po-Chien Luan. 2019. CNN and LSTM Based Facial Expression Analysis Model for a Humanoid Robot. (July 2019). https://ieeexplore.ieee.org/Xplore/home.jsp
[18] Jia Yin, Koppaka Ganesh Sai Apuroop, Yokhesh Krishnasamy Tamilselvam, Rajesh Elara Mohan, Balakrishnan Ramalingam, and Anh Vu Le. 2020. Table Cleaning Task by Human Support Robot Using Deep Learning Technique. (March 2020). https://www.mdpi.com/1424-8220/20/6/1698
[19] Widodo Budiharto, Vincent Andreas, and Alexander Agung Santoso Gunawan. 2020. Deep learning-based question answering system for intelligent humanoid robot. (September 2020). https://journalofbigdata.springeropen.com/articles/10.1186/s40537-020-00341-6
[20] Jiaji Yang and Esyin Chew. 2020. A systematic review for service humanoid robotics model in Hospitality - International Journal of Social Robotics. (November 2020). https://link.springer.com/article/10.1007/s12369-020-00724-y#citeas
[21] Nicolas Duczek, Matthias Kerzel, and Stefan Wermter. 2021. Continual learning from synthetic data for a humanoid exercise robot. (February 2021). https://arxiv.org/abs/2102.10034
[22] Swagatam Biswas and Sheikh Rafiul Islam. 2021. Machine Learning-Enabled Human Activity Recognition System for Humanoid Robot. (April 2021). https://www.researchgate.net/publication/351086719_Machine_Learning-Enabled_Human_Activity_Recognition_System_for_Humanoid_Robot
[23] Simge Nur Aslan, Recep Özalp, Ayşegül Uçar, and Cüneyt Güzeliş . 2021. New CNN and hybrid CNN-LSTM models for learning object manipulation of humanoid robots from demonstration - cluster computing. (June 2021). https://link.springer.com/article/10.1007/s10586-021-03348-7
[24] J.A. Rojas-Quintero and M.C. Rodríguez-Liñán. 2021. A literature review of sensor heads for Humanoid Robots. (June 2021). https://www.sciencedirect.com/science/article/pii/S0921889021001196#section-cited-by
[25] Somchai Pohtongkam and Jakkree Srinonchat. 2021. Tactile Object Recognition for Humanoid Robots Using New Designed Piezoresistive Tactile Sensor and DCNN. (September 2021). https://www.mdpi.com/1424-8220/21/18/6024
[26] Prashani Jayasingha. 2021. Nao humanoid for physical therapy rehabilitation. (2021). https://www.doria.fi/handle/10024/182994
[27] Anna Lekova, Paulina Tsvetkova, Tanio Tanev, Peter Mitrouchev, and Snezhana Kostova. 2022. Making humanoid robots teaching assistants by using natural language processing (NLP) cloud-based services. (June 2022). https://www.extrica.com/article/22720
[28] Andrea Eirale, Mauro Martini, Luigi Tagliavini, Dario Gandini, Marcello Chiaberge, and Giuseppe Quaglia. 2022. Marvin: An Innovative Omni-directional robotic assistant for Domestic Environments. (July 2022). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9322347/
[29] Daliang Zhou, Gang Chen, and Fei Xu. 2022. Application of deep learning technology in strength training of football players and field line detection of Football Robots. (June 2022). https://www.frontiersin.org/articles/10.3389/fnbot.2022.867028/full