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A Review of AI-Powered Autonomous System Using Machine Learning

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Abstract— **This study explores the concept, significance, and strategies of AI-Powered Autonomous Systems, focusing on machine learning frameworks. It integrates ideas like grayscale normalization, AI in bioinformatics, in-vehicle passenger monitoring, advanced robotics, autonomous driving, blockchain for training vehicles, and visible light communication. A comparative analysis highlights the advantages and limitations of these systems in various contexts. The study examines their applications across industries such as transportation, healthcare, manufacturing, and agriculture, emphasizing efficient decision-making, process optimization, and safety improvements. Leveraging machine learning algorithms, including ANN, DL, MLP, CNN, RNN, and SVM, these systems achieve high levels of automation and innovation. The study concludes by identifying research goals to advance the capabilities and trends of AI-Powered Autonomous Systems.**

***Keywords*— Autonomous Systems, Machine Learning, AI, Algorithms, SVM, Classification.**

I. Introduction

Artificial Intelligence (AI) has transformed industries by introducing innovative solutions to complex problems, with autonomous systems being one of its most groundbreaking applications. These systems, powered by machine learning, enable machines to operate independently and revolutionize technology. Despite advancements over the past six decades, the development of fully autonomous systems has been limited by the lack of foundational principles required for independent functioning [14]. Autonomous Systems (AS) are designed to perform complex tasks, incorporating reflexive, imperative, adaptive, and cognitive intelligence [19]. This paper focuses on the role of machine learning in enhancing these systems, which are reshaping industries such as transportation, healthcare, manufacturing, medical diagnostics, and more [11]. It examines methodologies, designs, challenges, and how machine learning improves decision-making in complex scenarios. The fusion of artificial intelligence, self-governing systems, and automated learning marks a major technological achievement. The paper explores AI-powered autonomy's future in decision-making, safety, and broader applications but lacks details on feature selection, dataset use and scalability. This research aims to contribute by analyzing the strengths, limitations, and transformative potential of AI-powered autonomous systems across industries.

II. Literature Review

A total of fifteen studies were reviewed, each employing AI and machine learning techniques in autonomous systems. Key findings from these studies are outlined below:

H. Abedi et al. [1] Suggested an AI-driven onboard passenger surveillance system utilizing affordable mm-wave radar, applying SVM, KNN, and RF algorithms with 97% accuracy. However, feature numbers were not mentioned.

D. Kothari et al. [2] Introduced grayscale normalization and AI for bioinformatics using machine vision techniques and CNN. Classification was achieved with CNN, SVM, and MLP, obtaining 87% accuracy, but no features were described.

M. Soori et al. [3] Proposed advanced robotics techniques using deep learning and machine vision but did not specify the dataset, number of features, or accuracy. Classification involved machine learning, clutter removal, and conventional algorithms, though details on dataset are missing but accuracy is 98%.

B. Blobel et al. [4] Discussed AI and autonomous systems in p5 medicine using CNN and RNN algorithms, without specifying datasets and accuracy 92%, limiting performance validation.

Kritika Rana et al. [5] Reviewed algorithms for autonomous cars, categorizing them into decision matrices, clustering, pattern detection, and regression algorithms. No accuracy data provided, but significant future impact on transportation was highlighted.

Yingxu Wang [6] Investigated the core principles of self-governing systems through a layered intelligence framework (HIM) incorporating five intelligence types and 16 behavioral patterns.

Yingxu Wang et al. [7] Investigated the structural and behavioral properties of autonomous systems using HIM with four intelligence features (reflexive, imperative, adaptive, cognitive) and datasets on intelligence, knowledge, and data.

G. Bathla et al. [8] Proposed autonomous vehicle methodologies using machine vision and neural networks, but lacked dataset definition and accuracy classification despite five methods being explored.

S. Grigorescu et al. [9] Surveyed deep learning techniques for autonomous driving, focusing on CNN, RNN, and DRL.

Using 1,300 data points, they classified techniques such as scene perception and motion control, achieved 93% accuracy.

M. O. Macaulay et al. [10] Developed robotic and autonomous inspection systems using machine vision, applying ANN, CNN, R-FCN, and RNN algorithms to two feature types. No accuracy data was reported.

Subhranil Das et al. [11] Developed an AI-based vision control system for autonomous vehicles, utilizing neural networks, probabilistic models, and heuristic optimization techniques. Algorithms such as ANN, SVM, Deep Learning, and MDP were implemented, demonstrating improved vision control for AUGV design through three AI-based techniques.

Danil Prokhorov [12] Explored AI in autonomous driving systems with DNN-based approaches for decision-making, achieving a classification accuracy of 99.46%.

D. H. Hagos et al. [13] introduced AI and tactical autonomy using ML and robotics. Their work includes five datasets. Applied Al and ML based algorithms for classification.

Jihene Rezgui et al. [14] implemented AV platooning using AI on the ALIVE platform. They defined six features, used DPA and PDMP algorithms, and achieved high accuracy.

Hai-Tao Zhang et al. [15] proposed a vision-based, adaptive learning approach for UAV landing on a moving ASV. Includes two feature sets, six modules, and parameter results.

III. RESEARCH METHODOLOGY

A. *System Design*

For describing the autonomous system based on machine learning using artificial intelligence, these input data must go through by the following steps:

1. Data collecting and data preprocessing
2. Feature extraction
3. Algorithms and Machine learning models
4. Validation and Evaluation
5. Performance Analysis and Results.

Here, fig-1 contains the system design.

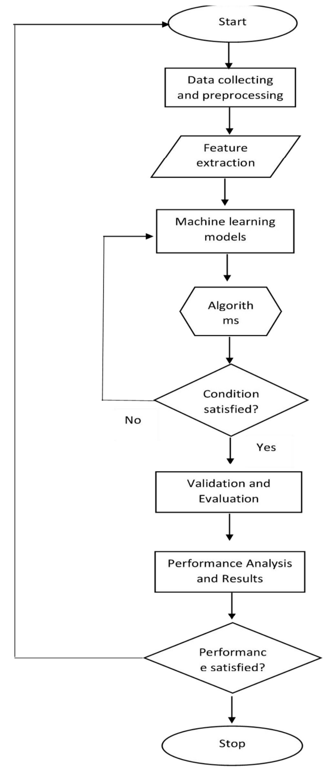

Fig. 1. System design.

B. *Data collecting & Pre-processing*

Collecting data from various sensors, such as GPS, cameras, radar, and lidar, installed in autonomous systems is crucial. Additionally, external data like traffic updates, maps from different sources, and continuous user commands are gathered to enhance system functionality. Specialized sensors provide environmental information, including images, location coordinates, and distance measurements.

Thresholding: Thresholding is a process that converts hue, saturation, or grayscale images into binary images, comprising only black and white pixels. This technique is commonly used to isolate significant regions within an image while disregarding less relevant areas.

Neural Networks: Neural networks are computational models capable of learning from provided data to perform various tasks, such as segmentation, generation, regression, and classification. These networks are structured in layers of interconnected neurons, which process input data to produce higher-level representations.

Clustering: The K-means clustering algorithm, a self-learning approach, is employed to distinguish relevant areas from the background. Before applying K-means, partial stretching enhancement is used to improve the image quality. In medical imaging, fuzzy c-means (FCM) clustering is among the most commonly utilized techniques regarding unsupervised clustering. diagnosis image processing, a crucial application, involves identifying and separating anatomical structures from medical images.

C. *Feature Extraction*

Attribute extraction involves converting unprocessed data into numerical representations that can be efficiently analyzed, while retaining the crucial information from the initial dataset.

The methods for Attribute extraction differs based on the nature of the data, such as:

Image Processing: Feature extraction from images involves techniques such as Boundary detection filters, Gabor kernels, and Gradient Orientation Histograms (GOH).

Text Data: Natural language processing (NLP) techniques like word embeddings, TF-IDF, and Bag of Words are used to extract meaningful features from text.

Audio Processing: Audio signal processing relies on features such as Mel-frequency cepstral coefficients (MFCCs) and spectral differentiation.

Numerical Data: Features derived from numerical data types (e.g., float or integer), such as height, age, and salary, are straightforward numerical representations.

Binary Features: These are a specific type of categorical feature with only two possible categories, such as has_subscription (true/false) or is_smoker (yes/no).

D. Classification

Support Vector Machine (SVM) Algorithm: SVM is a commonly used supervised learning technique for classification and regression problems. Its main objective is to identify the ideal decision boundary or hyperplane that separates an n-dimensional space into separate categories, facilitating the classification of new data points. The algorithm gets its name, "Support Vector Machine," from the support vectors, which are the data points closest to the decision boundary that influence its position.

Convolutional Neural Networks (CNN): CNNs are a crucial type of neural network widely employed in image identification and categorization tasks. They are used in fields like object identification, face recognition, and scene annotation. When an image is input into a CNN, it is processed and classified into one of several categories, such as dog, cat, tiger, etc. CNNs process images through layers of convolution, pooling, and fully connected layers, with filters (kernels) applied at each stage to extract meaningful features.

Clustering Algorithms: Clustering algorithms are essential in data exploration, outlier detection, and pattern recognition [16]. Similar to reinforcement learning and neural networks, clustering works with noisy, diverse, and largely unstructured data to uncover meaningful insights. Common clustering methods include K-Means, Mean Shift, Divisive Hierarchical, Hierarchical Agglomerative, and Gaussian Mixture Models.

Decision Matrix Algorithm: This algorithm is a tool for analyzing, evaluating, and ranking relationships between data values and information. It is primarily used in decision-making processes. For example, autonomous vehicles may use these algorithms to decide whether to stop, turn left, or turn right, based on the confidence levels in identifying, classifying, or estimating the movement of objects.

Neural Networks Technique: Neural networks are computational models inspired by the architecture and operation of the human brain. They mimic the synaptic connections between neurons to identify relationships within large datasets. These networks are commonly utilized for their capacity to recognize patterns, make predictions, and perform classifications based on complex data inputs.

IV. EVALUATION

The research papers employed various methods for validation and evaluation, including SVM, classification, regression, clustering methods of algorithms.

TABLE I. TABLE OF EVALUATION OF AI-POWERED AUTONOMOUS SYSTEM USING VARIOUS MACHINE LEARNING TECHNIQUE

Method/ WorkDone	Classifier	Segmentation algorithm	Accuracy
1. H. Abedi et al. (2021)	SVM, KNN and RF	k-means clustering	97%
2.D. Kothari et al. (2021)	CNN, SVM and MLP	NM	87%
3. M. Soori et al. (2023)	ML, clutter removal, conventional	k-means clustering	98%
4. B. Blobel et al. (2021)	CNN and RNN	k-means clustering	92%
5. Kritika Rana et al. (2022)	Decision matrices, clustured, pattern detection and regression-based	k-means clustering	NM
6. Yingxu Wang-2019	NM	k-means clustering	NM
7. Yingxu Wang et al. (2020)	ANN	Adaptive intelligence	Predictive analysis
8. G. Bathla et al. (2022)	NN, genetic algorithm	convolutional neural network	NM
9. S. Grigorescu et al. (2019)	CNN, RNN and DRL	Semantic Segmentation	93%
10. M. O. Macaulay et al. (2022)	ANN, CNN, R-FCN and RNN	Mask R-CNN, MAP	Compared Accuracy
11. Subhranil Das et al. (2019)	ANN, SVM, MDP, Deep learning	c-means clustering	NM
12. Danil Prokhorov (2019)	NM	CNN	99.46%
13. D. H. Hagos et al. (2022)	ML and AI	Various model	Predictive analysis
14. Jihene Rezgui et al. (2020)	DPA, PDMA	Semantic segmentation	NM
15. Hai-Tao Zhang et al. (2021)	NM	CNN	Predictive analysis

V. RESULT AND ANALYSIS

SVM operates by representing data, identifying an optimal hyperplane, maximizing the margin between data classes, and employing the kernel trick to handle non-linear data effectively. Two essential parameters in SVM are the **C parameter**, which manages the balance between a smooth decision boundary and accurately classifying training points, and the **Gamma parameter**, which determines the impact of individual data points on the decision-making process.

TABLE II. ACCURACY COMPARISON

SVM Accuracy Comparison		
Application	**SVM Accuracy (%)**	**Notes**
Image Classification	98% (for bigger datasets) [3]	SVM excels in image classification with large datasets
Text Document Classification	95.5% (OvA method) [11]	SVM performs well, but OvA method is time-consuming
	93% (Random	Random Forest (RF) slightly

	Forest) [10]	outperforms SVM
	92.2% (KNN) [1]	KNN is effective but has slightly lower accuracy
Quality Control & Fault Detection	92% - 98% [3][4][9]	SVM consistently provides high accuracy in quality control and fault detection scenarios
Remote Sensing [4][3]	92% (worst case)	SVM still performs reasonably well even in worst- case scenarios for remote sensing applications
	98% (best case)	

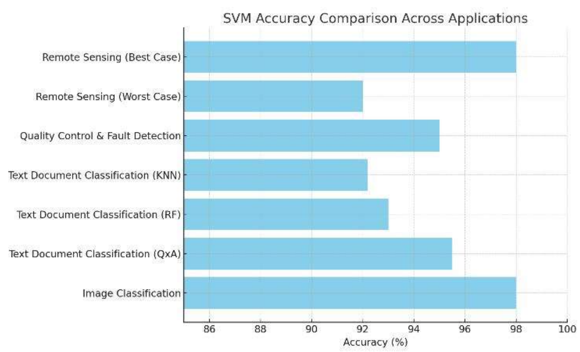

Fig. 1. SVM accuracy comparison across different applications.

Here is a bar chart visualizing the SVM accuracy comparison across different applications based on the provided table. Let me know if you need additional analysis or modifications to the chart.

VI. Conclusions

This study has explored the significance of Artificial Intelligence and Machine Learning in self-driving systems, emphasizing the algorithms and techniques utilized. It provides an overview of various algorithms, data sources, preprocessing techniques, feature extraction methods, and machine learning models applied in these systems. Advanced machine learning models and algorithms, such as Support Vector Machines (SVM), Convolutional Neural Networks (CNN), and Decision Matrix Algorithms, have been employed in a range of applications, demonstrating the adaptability and effectiveness of these technologies. This research demonstrates how AI-driven autonomous systems enhance efficiency and accessibility in transportation, healthcare, manufacturing, and agriculture. By enabling automation, intelligent decision-making, and streamlined operations, these systems improve safety, reduce errors, and transform industries. Nevertheless, additional studies are required to tackle data security, transparency, and algorithmic bias for ethical and responsible AI deployment.

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