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Standard Essential Patents Data Study of the Impact of Artificial Intelligence on Intelligent Connected Vehicle Technological Advancement

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Abstract: - This research employs a machine learning-based text mining algorithm and the international patent classification (IPC) co-occurrence network approach, utilizing patent documents submitted from 2015 to 2022 to empirically examine the influence of artificial intelligence (AI) on modern electric car progress. The research illustrates the dynamically shifting structure of the fusion of AI and electric car technology and indicates how AI has impacted electric car technological advancement through time. It is based on classified artificial intelligence techniques. This research shows that artificial intelligence speeds up the automated process of driving in electric cars, that the AI technique often employed in electric vehicles has undergone modifications long period, and that the technical aspects of electric cars that AI impacts have shifted as well.

Keywords: Artificial Intelligence (AI), international patent classification (IPC), co-occurrence network approach, electric car, standard essential patents, security, and authentication.

1. Introduction

The fast modernization of industry has heightened the issue of worldwide energy scarcity in the past few years. Additionally, enormous production of greenhouse gases and environmental pollution has resulted from rising urbanization and increased use of fossil fuels, which poses a huge danger to global energy efficiency. The Paris Agreement predicts a three percent rise in average global temperature this century. In this situation, electric vehicles (EVs) are gaining popularity due to their low ecological damage, low energy consumption, and low emissions. There has been a significant movement towards EV manufacturing because of improvements in the development of batteries, power grid administration, and the pressing environmental need to reduce greenhouse gas release [1]. Several nations have proposed goals and plans for the advancement of EV technology. In recent years, sales of EVs have skyrocketed thanks to numerous favorable measures. However, EV advances are not yet fully developed, and there are still certain issues to be resolved, such as the inability to go over large distances and the length of time required to fully charge the battery. As a result, the public's attention has shifted from conventional automobiles to electric vehicles (EVs) as people have grown more concerned about protecting the environment [2]. In 2017, transportation companies were responsible for 24 percent of the world's greenhouse gas emissions, or 8040 metric tonnes (MT) of CO2, from burning fossil fuels in the movement of people and goods by land, air, and sea. By 2035, the worldwide desire for transportation fuel will be projected to increase by 40%. To decrease greenhouse gas discharge and conform to the future of sustainable growth, the transportation industry must now increase its use of environmentally suitable transportation fuel. The analysis from the International Energy Agency (IEA) suggests that transportation industries have the potential to make a difference in 21% of total CO2 reductions by 2050 [3]. In order to combat climate change and meet the ambitious goal of reducing CO2 emissions, we must transition to new forms of transportation. By decreasing emissions from internal combustion engine cars, electric vehicles (EVs) have the potential to inspire innovation that may help mitigate

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these global concerns. By eliminating the need for fossil fuels, foreign energy imports, and air pollution, electric cars may help strengthen energy independence and environmental protection. Suppose the power used by EVs is produced using energy from renewable sources like wind or solar. In that case, they help lessen our reliance on foreign energy by lowering fuel imports and contributing to environmental protection. Since the economic impact of EVs is expanding, governments in nations at the forefront of technological innovation, most notably China, are taking steps to encourage the widespread use of EVs and support the EV sector. There has been a tremendous surge in the spread of electric cars in recent years, with over half of 2018's worldwide sales of 1.98 million EVs occurring in China [4]. Technology for electric cars has advanced significantly in recent years, mirroring the rapid growth in their popularity. Recent times have seen significant advancements in electric vehicle technology, with an increased driving range and decreased battery prices from about $1,000 per kilowatt hour in 2010 to less than $156/kWh in 2019. As the number of electric cars, automatic cars, and share mobility rises, and mobility industries emerge, the transport sector is becoming more motorized and digitalized [5]. Maintaining safe and dependable electricity systems is more important than ever as electric vehicles become increasingly integrated into grid networks. In addition, if we want to reduce CO2 discharge from widespread deployments of electric cars drastically, we must charge them using sustainable energy sources like wind and solar power. In spite of this, methods must be developed to assure the dependability of electric power networks in light of the intermittent nature of these forms of sustainable energy [6]. Attractive technologies are those that show great promise for future growth and have the ability to spearhead technological advancement in their respective domains. In present, the efficient growth of this subject may be driven by the identification of potential technologies in EVs. But to evaluate them, useful data is usually required. Many studies attempt to glean relevant information from patents in order to discover prospective inventions from the standpoint of technical qualities; this is because patents include significant technological knowledge and frontier knowledge [7]. Technology areas such as power sources, charging resources, and power management systems have been recognized through patent evaluation as critical to the EV industry, and promising innovations like wireless charging and fuel cell development have been determined through the same process. The proliferation of e-commerce has also increased the availability of consumer feedback in the form of online reviews. By studying and analyzing this data, businesses will be better equipped to respond to technological industry shifts and consumer preferences. To better assess technical supremacy and find innovative innovations, internet evaluations give a unique viewpoint [8]. It is important to construct a policy portfolio on the development of AI based on empirical evaluation since AI is anticipated to progress EV technology and impact efficient electrical systems operations. Interest in the use and efficacy of AI is on the rise, but there is still a shortage of long-term empirical studies on AI's impact on technical innovation in electric cars. Research showing a pattern of integration between AI and EV technologies is few. Furthermore, no published studies categorize each AI technique and period to illustrate the impact of AI on EV innovations. In response to these gaps, this study employs a machine learning-related text mining approach and International Patent Classification (IPC) co–occurrence network evaluation on patent data documents submitted between 2015 and 2022 to examine the impact of AI on EV technology advancement empirically.

2. Related works

Many nations have hastened the creation of electric cars in an effort to lessen their reliance on oil and their environmental impact. Battery electric cars (EVs), in particular, are seen as a potential answer to today's energy crises and ecological issues. That study offers a thorough analysis of the technological progress made in EVs and the novel developments on the horizon for their potential future use. Battery packs, charging facilities, electric motors and controls, and recharging stations for EVs are all briefly discussed [9]. As part of their regular duties, innovation managers analyze new technologies' possible commercial, regional, industrial, and user impacts across various innovative domains. Such assessments are often used to determine where to invest in the development or implementation of technology, and they are based on a synthesis of data from many data sources. To aid in that selection process, they use a semantic bridge between trend and patent data to discover and analyze potential areas of innovation. They extend their approach to the setting of the blockchain system, illustrating how patent information can be used to assess innovation fields and how trend information can be utilized to discover development fields [10]. The latest AI arms race has begun thanks to the potential of AI to boost the economy and people's standard of living. Risk capital expenditures power this new development. We investigate the impact of VC and organizational risk capital contributions on developing technologies linked to AI. They discover AI-related growth and investment features by analyzing a collection of 29,955 U.S. patents from 1970 to 2018, which includes 1484 U.S. patents awarded to 224 VC-backed start-ups. They also create a novel firm-level metric for information coupling and use it to investigate the impact of knowledge connection on venture capital risk capital choices in new areas of artificial intelligence. Their research indicates that the depth of a patent's technical domains is less important than expertise coupling when predicting VC investment in novel technologies [11]. More than 99% of all automobiles on the road are powered by combustion machines, which rely on fossil fuels as their energy vector. The prevalence of electric cars and the relevance of their role in mitigating pollution from rapidly expanding cities are both on the rise. However, several issues remain, including high CO2 emissions, inadequate storage, and an unreliable energy source. For a smooth transition to full modernization, however, it is necessary to upgrade an enormous number of cars whose power plants rely mostly on combustion. Consequently, the surviving internal combustion engines must evolve into more effective and environmentally friendly energy converters. Policymakers and corporate leaders must be aware of evolutionary tendencies in order to make sound choices. That research set out to use patent data to chart the development of engines with combustion technology and identify its primary themes. Through the use of a Logistics model, they were able to ascertain the present level of technical progress and analyze the sub-technologies featuring the most promising growth and spread prospects [12]. Several reasons, including falling prices and increased climatic and environmental consciousness, have contributed to EVs' rise in popularity. The present status of electric car battery technological advances, especially new research opportunities, and challenges, are highlighted. In particular, the state and prospects of the EV market worldwide are analyzed. Since batteries are crucial to EVs, this article provides a comprehensive overview of battery technologies ranging from lead-acid to lithium-ion. In addition, they evaluate the various authority and battery control concepts and the existing regulations for charging electric vehicles [13]. Lithium-ion cells are in almost every piece of technology we use regularly. To help meet the current commitments to reduce emissions of greenhouse gases, these batteries are utilized in electric and hybrid automobiles. That has led to a worldwide growth in the demand for electric vehicles. Li-ion batteries are the key to an environmentally friendly future without gasoline-powered cars since they are built of crucial metals that might see supply interruptions in the short term. Techniques of new energy design, recovery methods, logistical revers, and policies for equitable growth all benefit from an awareness of the state of affairs and its potential evolution. That report covers the cars that are already in use worldwide and those that will be in use shortly. The BRICS countries will be largely responsible for the increase since their populations are expected to double from 1.3 to 2 billion between now and 2030 [14]. To guarantee battery power security in EV applications, the ability to diagnose charging capacity abnormalities is crucial. In that piece, they suggest a data-driven approach to diagnosing battery charging capability using large amounts of operational data from actual EVs. A tree-based forecasting system uses a polynomial feature combining the recharging rate, humidity, state of charge, and cumulative driving kilometers as inputs. The abnormality in the battery's ability to charge is then diagnosed using statistics by examining the error spectrum of several data samples [15].

3. Methodology

The framework of the methodology is depicted in Figure 1. It consists of data collection, data preprocessing, and techniques of ML-related text mining and (IPC) co–occlusion network analysis.

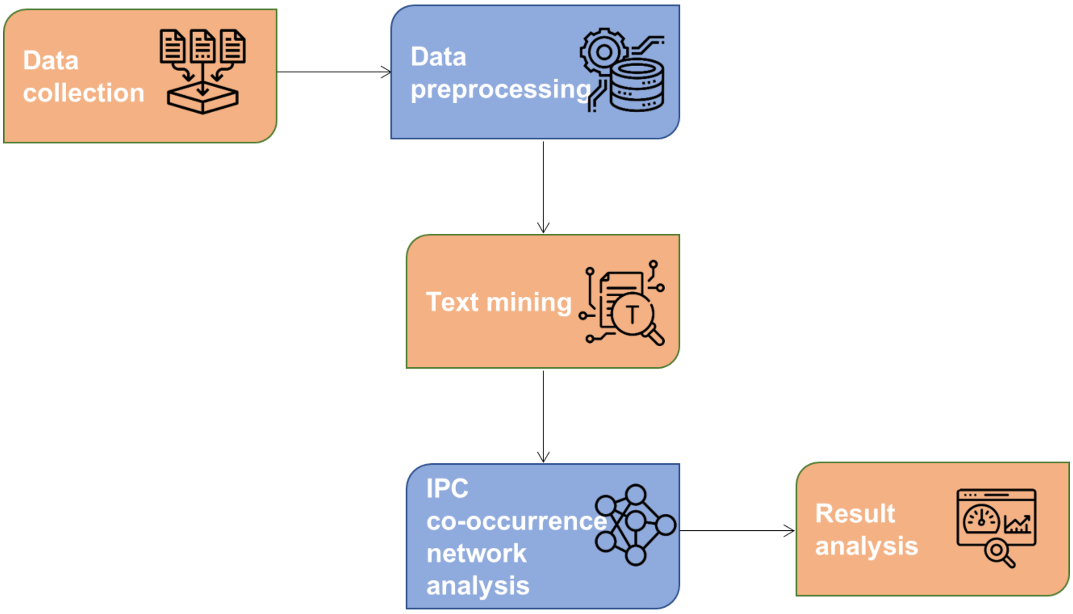

Figure 1: Framework of methodology

A. Data collection

This research examines the impact of AI on the development of new technologies for electric vehicles between 2015 and 2022 by mining patent papers using ML-powered text mining algorithms and doing an IPC co-occurrence network analysis. Information on patents was gathered by compiling their textual descriptions and their International Patent Classification codes, applicants, and filing dates. The "KIPRIS (Korea Intellectual Property Rights Information Service)" datasets, virtual patent records, were first scoured for relevant information. Data on local and international intellectual property rights may be found in KIPRIS, a patent search tool the Korean Intellectual Property Office offers. The KPRIS has a website where the service may be used for free. From January 1, 2015, through December 31, 2022, we compiled information on patents filed with the "USPTO (United States Patent Trademark Office), the SIPO (Intellectual Property Office of China), the JPO (Japan Patent Office), and the EPO (European Patent Office)." The following are justifications for starting the patent application process in 2015. First, during the subsequent wave of the oil crisis in 2022, interest in alternative energy sources likely rose, which might have led to an uptick in EV-related technological advances and patent applications. Following the 2015 oil crisis, several developed nations aided in the manufacturing of EVs, and the number of EV patents has been on the rise ever since. Artificial intelligence, however, has been underutilized in EVs.

Every AI technique was chosen after an extensive analysis of the theoretical foundations of AI algorithms. Based on the history of AI and explanations of algorithms, we separated typical AI algorithms into subcategories that were used up to 2000, when ML algorithms began to be utilized seriously. The abbreviated for individual AI algorithms are commonplace; for example, "artificial neural networks (ANN)," "genetic algorithm (GA)," "support vector machines (SVM)," "deep belief networks (DBN)," "particle swarm optimization (PSO)," etc. To provide more accurate results and less background noise, we searched for abbreviations and whole words using all available AI algorithms at once. Searching for 'support vector machine,' an affiliate technique of ML, and 'EV,' or 'automatic car,' together is an example of looking for patents look up for this study because it monitors the impact of AI on EV methods. The '*' mark, which denotes 'and,' may be used to do a combined search for several terms; for instance, "support vector machine" and "electric vehicle." We looked at patent data for four time periods: (i) 2015–2016, (ii) 2017–2018, (iii) 2019–2020, and (iv) 2021–2022. There are caveats to using patent data in this way. After submitting a patent application to the patent office, the public typically has access to the patent 18 months later.

B. Data preprocessing

The abstract of patents, unorganized textual data providing summarized crucial technology data, was analyzed in this research, with preprocessing performed using the KoNLP package on the R library. Natural language processing encompasses a wide range of methods for automatically analyzing linguistic occurrences, translating them into a form that computers can understand, and then re-expressing them in a human-readable form. The translation into a format from which data may be retrieved is necessary since patent papers are unorganized text documents.

C. Text mining

To examine the influence of AI on EV systems and to analyze the connections among words in this context, we used the t-Stochastic Neighbors Embedding (t-SNE) method. The t-SNE model is an ML-based approach that returns an outcome on a low-dimensional location by keeping the neighbors of high-dimensional information intact. Despite its name, the t-SNE algorithm is only a tweak on the classic SNE method. SNE uses the Gaussian spectrum to determine how closely two points in low-dimensional space are related, whereas t-SNE uses the Student t-distribution instead. Due to its graph-like output, t-SNE typically operates in a 2-dimensional space. In t-SNE, comparable data is projected onto a 2D point close by, while dissimilar data is projected to further away. The t-SNE uses a distribution of normal probabilities to calculate the separation of the higher dimensional data. The t-distribution with one degree of freedom is used to test the significance of the difference. Since the t-distribution and the bottom of the graph are longer than the typical distribution, utilizing the t-distribution to project to a lower dimensional space preserves the state of the data at close range while expanding the declaration of the data at greater distances. Compared to a normal distribution, the tail of the t-distribution is much greater. As a result, when data is projected to the least dimensionality using the t-distribution, the previously closed points move closer together. In contrast, the previously far-apart issues move farther apart.

D. Network study of co-occurrence in the IPC

A network evaluation of IPC co-occurrences is usually utilized to spot convergent technology. When filing for a patent, you must provide a patent classification number that reflects the area of technology your invention serves. Each of the eight sections of the International Patent Category corresponds to a letter of the alphabet, from A to H.

When a patent has relevance to more than one area of technology, it may be assigned more than one categorization code. When numerous IPC codes appear in a single patent, it indicates technological convergence and is called "IPC co-occurrence." IPC co-occurrence between distinct patents allows for the identification and analysis of the dissemination of technical information. Using patent data from 2001–2015, investigators used IPC co-occurrence network evaluation to foresee the shape of technological convergence. In this research, we show how integrating AI and EV technology is a dynamic process by analyzing the IPC co-occurrence system, and we also identify the patterns of convergences across elementary technologies throughout time. Although the IPC co-occurrence network evaluation was conducted on a 10-year basis, patent data from 2015 and 2020 were analyzed together because of the very small number of such data before the year 2000.

4. Result analysis

Employing AI to examine the historical pattern of patent requests for EV technology reveals that the total amount of patent use cases did not reach statistical significance until 2021 but has surged dramatically. In 2015–2016, there were just 10, but in 2017–2018, there were 120, and in 2019–2020, there will be 522 patents. More than four times as many patents were issued in 2021-2022 than in the preceding two years combined. This trend likely stems from the IT boom that kicked off in earnest in the latter half of 2016 and continued into early 2018, as well as the active integration and use of AI in electric car systems. The worldwide drive to reduce greenhouse emissions may also have influenced the recent uptick in electric car innovation. USPTO patents total 2,394, followed by EPO patents totaling 407, SIPO patents totaling 201, and JPO patents totaling 115. The USPTO has more patent filings than any of the other three patent offices put together. The total number of patents filed with each patent office is shown in Table 1 and Figure 2. In 2016, the number of patent applications submitted to the USPTO, EPO, and JPO was maintained at two-three, while no patent applications were introduced to the SIPO until 2018. While only 19 and 20 patents were submitted with the EPO and JPO, respectively, between 2017 and 2018, the number of patents document with the USPTO climbed to 81. This chasm became much wider in 2019. While the EPO and the JPO both had relatively flat growth in patent filings, the United States Patent and Trademark Office saw a 431 rise. In 2019, SIPO received its first-ever patent request submission. Have been 1880 patents filed with the USPTO since 2021, 333 with the EPO, and a very low 63 with the JPO. Since the advent of deep learning in 2021, the number of patent applications submitted with the SIPO has risen dramatically. Until 2021, more patent applications were introduced to the JPO than the SIPO. Since Chinese businesses make up the bulk of patent applications at SIPO, it would suggest that advancements in electric vehicle technologies that use artificial intelligence have also been developing quickly in China.

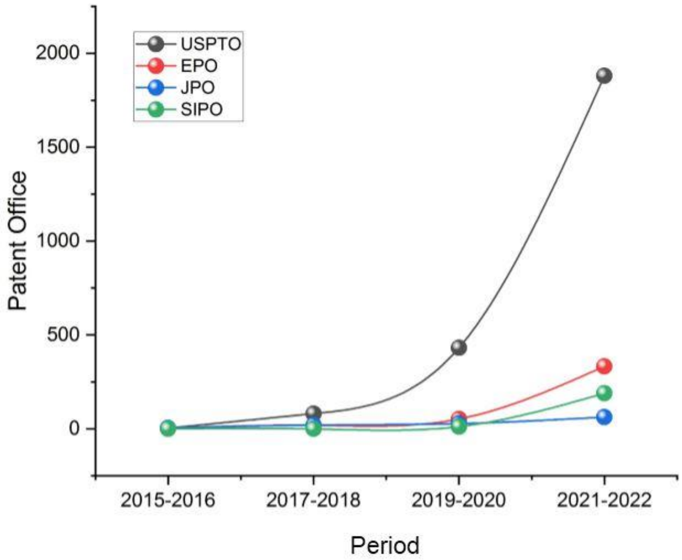

Figure 2: A patent for an electric car system that uses AI has been filed at the four patent agencies by that time

Table 1: The end outcome of collecting patents from 2015 until 2022

Period	Patent Office			
	USPTO	EPO	JPO	SIPO
2015-2016	3	3	4	0
2017-2018	81	19	20	0
2019-2020	431	52	28	12
2021-2022	1880	333	63	189

For this analysis, we gathered data from 3,123 patents covering AI-based technologies for electric vehicles. Table 2 displays the outcomes of each AI algorithm's analysis of the patent data acquired for EV technology. From 2015 to 2022, the neural network algorithm was the most sought-after AI algorithm 968 times, followed by the fuzzy approach 691 times, the genetic algorithm (GA) 225 times, expert systems 134 times, and the Monte Carlo 133 times.

Table 2: Overall outcomes from an AI-powered patent search on electric vehicles

The advancement of electric vehicles employs an AI system	Patent office				
	USPTO	EPO	JPO	SIPO	Total
NN	760	139	25	44	968
Fuzzy	509	68	34	80	691
SVM	184	61	9	10	264
Genetic algorithm	148	41	9	27	225
Expert system	104	18	10	4	134
Monte Carlo	97	13	4	19	133
Decision trees	90	10	0	0	100
KNN	81	7	2	0	90
K-means	62	7	6	4	79
PCA	49	13	4	0	66
RNN	53	5	2	0	60
Random forest	40	3	2	0	45
CNN	40	2	0	0	42
DNN	28	0	2	4	32
Naive Bayes	26	5	0	0	31
Particle swarm optimization	23	6	10	14	53
Evolutionary algorithm	22	6	3	2	33
Evolutionary learning	22	6	3	2	33
Bagging	22	2	0	0	24
Markov decision process	14	2	2	2	20
DBN	12	3	0	0	15
Hierarchical clustering	9	4	0	0	13
Q-learning	7	2	2	2	15
Autoencoder	6	0	0	0	6
Spatial application grouping based on density and noise	5	2	0	0	7
Ant colony optimization	3	2	2	2	9
Collective learning	2	0	0	0	2
Boltzmann machine	2	0	0	0	2
Deep q-learning	0	0	0	0	0
Deep Boltzmann system	0	0	0	0	0
Total	2396	427	131	216	3123

Looking at patent data chronologically by main algorithms, practically all have shown steady growth over time. In no algorithms did it indicate a decline. Even if deep learning has been regarded as the dominant AI algorithm since 2020, it is clear that traditional artificial intelligence methods like fuzzy logic, algorithmic genetics, and expert systems are still widely used in EV technology shown in Figure 3 and Table 3. After 2021, investments in NN and support vector machines skyrocketed. The freshly invented techniques that appeared and were actively employed for each era are distinct, and the collected technique knowledge is often used after a certain time frame. Thus, the development rate of algorithms would also vary over time. The fuzzy system, for instance, has been around for quite some time and is still actively utilized in the automated control of electrical items. The popularity of the machine learning methods NN and SVM, both excellent predictors and classifiers, has skyrocketed in the last year. NN and SVM have been used to predict and classify electric cars' battery capacities and driving ranges. Deep learning is only being utilized seriously from 2021; it has yet to be employed in EVs before 2020.

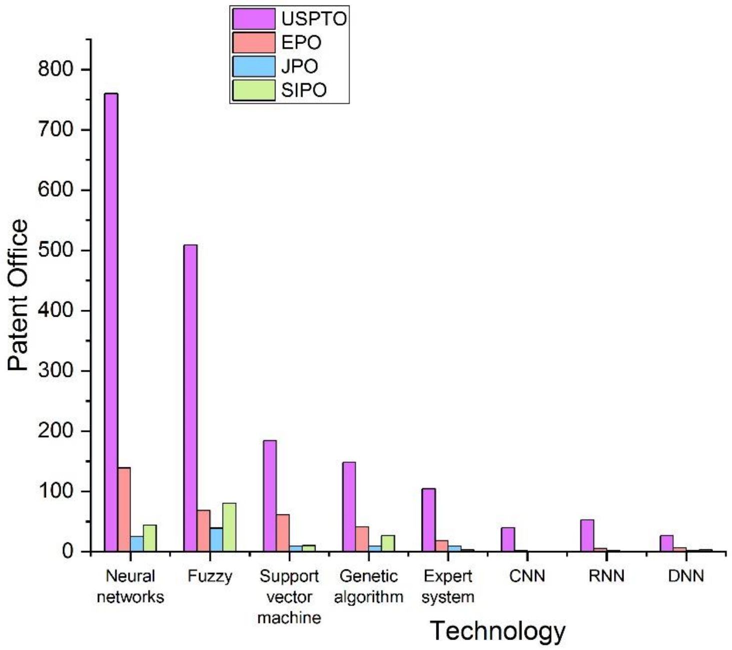

Figure 3: The direction of the top AI methods used for EV over time and by the group.

Table 3: Comparison of top AI algorithms with several technologies

Technology	Patent Office			
	USPTO	EPO	JPO	SIPO
Neural networks	760	139	25	44
Fuzzy	509	68	39	80
Support vector machine	184	61	9	10
Genetic algorithm	148	41	9	27
Expert system	104	18	9	3
CNN	40	2	0	0
RNN	53	5	2	0
DNN	27	6	2	3

Patents for electric vehicle (EV) technologies that use deep learning methods are shown in Figure 4 and Table 4. The USPTO receives most patent applications for deep learning algorithms like RNNs, CNNs, and DBNs, while the JPO and SIPO receive very few. USPTO saw the most use of recurrent neural networks (RNNs) (53 patents), followed by CNNs (40 patents), and finally, deep neural networks (27 patents). A neural network that may reflect data by retracing its steps is called a recurrent Neural Network (RNN). RNNs are often used to learn voice data or natural language because of their ability to learn with the help of materials, such as time-series data. The most widely used DL technique is the convolutional neural network. Its primary use is in image recognition, and its core concept is simplifying complicated visual elements into smaller ones. Recent improvements in the algorithm, technology, and large data have allowed CNN to outperform traditional categorization and feature identification methods. Using various picture datasets numbering in the millions and learning them with CNN has overcome the overfitting issue. Results from the patent of the EV method using DL algorithms allow for two estimates: USPTO is at the forefront of using DL the EV technology, which includes voice data, NLP, and image authentication technology.

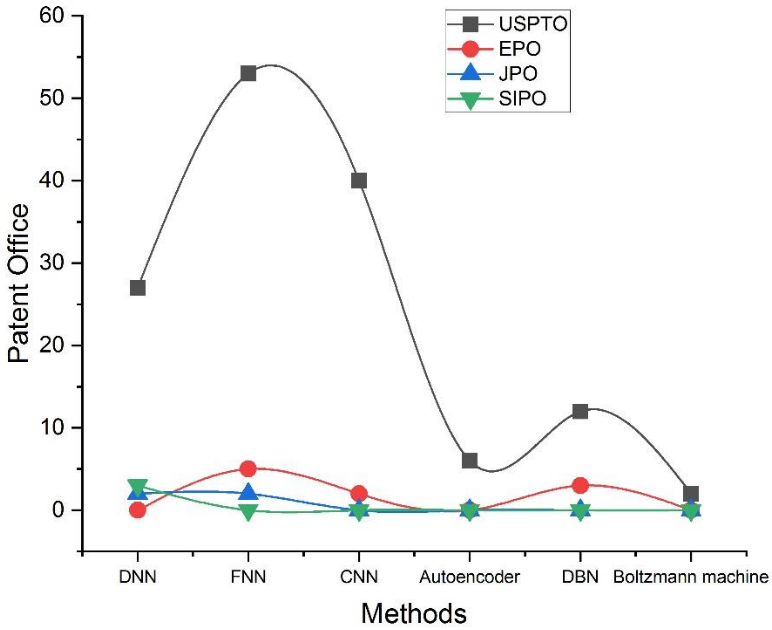

Figure 4: DL techniques are used in the technology for electric vehicles.

Table 4: Comparison of DL techniques powered in EV

Methods	Patent Office			
	USPTO	EPO	JPO	SIPO
DNN	27	0	2	3
FNN	53	5	2	0
CNN	40	2	0	0
Autoencoder	6	0	0	0
DBN	12	3	0	0
Boltzmann machine	2	0	0	0

5. Conclusion

This study experimentally investigated how AI has altered EV technology utilizing text mining based on machine learning and IPC co-occurrence system assessment using patent documents. This research used patent data from 2015-2022 to show how the integration and use of AI in automotive technologies are changing over time and to expose the consequences of convergence between AI and EV technology advancement. The results of this investigation demonstrate that (i) AI influences the forecasting of battery life and imposing time and (ii) AI causes the computerization of EVs, and (iii) AI has been more prevalent in the areas of computerization and optimization in EV lately. These results imply AI helps advance an energy system with a low by increasing the pace at which electric cars are adopted and automated. The use of AI in electric cars is evolving, partly due to the rapid and extensive pace of AI's technical development. Knowledge dissemination and the development of an innovation ecosystem, both of which may help to find promising new areas of technology, can benefit from government policy.

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