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# A Comparative Study of Machine Learning Techniques and its Recent Applications

C.Poornima, M.Sc., M. Phil., S.Gowthami, M.Sc., M.Phil., B.Ed.,

Assistant Professor, Department of Computer Applications, Sri Vasavi College (Self - Finance Wing), Erode,  
Tamil Nadu, India

Assistant Professor, Department of Computer Science, Sri Vasavi College (Self - Finance Wing), Erode,  
Tamil Nadu, India

**ABSTRACT:** Data from the Internet of Things (IoT), cybersecurity, mobile, social media, business, and health are all abundant in the digital world in the present Fourth Industrial Revolution (4IR or Industry 4.0). Understanding artificial intelligence (AI), in particular machine learning (ML), is essential to analyzing these data intelligently and creating the associated intelligent and automated applications. There are many different kinds of machine learning algorithms in the field, including supervised, unsupervised, semi-supervised, and reinforcement learning. Additionally, deep learning, a subset of a larger family of machine learning techniques, has the capacity to intelligently evaluate data on a huge scale. We provide a thorough analysis of various machine learning techniques in this paper, which can be used to improve an application's intelligence and capabilities. Explaining the fundamentals of multiple machine learning approaches and their suitability for use in a wide range of real-world application areas, including cybersecurity systems, smart cities, healthcare, e-commerce, agriculture, and many more, is thus this study's primary contribution. On the basis of our investigation, we also point out the difficulties and possible lines of inquiry. The overall goal of this article is to be a resource for experts in academia and industry, as well as for decision-makers in a variety of real-world scenarios and application domains, especially from a technical standpoint.

## I. INTRODUCTION

In recent years, machine learning (ML) and artificial intelligence (AI) have expanded quickly in the context of data analysis and computing, which usually enables the applications to operate intelligently. Referred to as the most popular newest technologies in the fourth industrial revolution (4IR or Industry 4.0), machine learning (ML) often gives systems the ability to learn and improve from experience automatically without being specifically programmed. Using new smart technologies like machine learning automation, "Industry 4.0" often refers to the continuous automation of traditional manufacturing and industrial processes, including exploratory data processing. Machine learning algorithms are therefore essential for the intelligent analysis of these data and the creation of the related real-world applications. As briefly covered in Sect. "Types of Real-World Data and Machine Learning Techniques," the learning algorithms can be divided into four main categories, including supervised, unsupervised, semi-supervised, and reinforcement learning in the field. Based on data gathered from Google Trends during the last five years, Fig. 1 illustrates the growing popularity of different learning methods. The figure's x-axis shows the precise dates, while the y-axis displays the associated popularity score, which ranges from 0 (lowest) to 100 (highest). The popularity indicator values for these learning styles are low in 2015 and are rising daily, as shown in Fig. 1. These figures encourage us to research machine learning in this paper, which can be useful in the actual world through automation brought about by Industry 4.0.



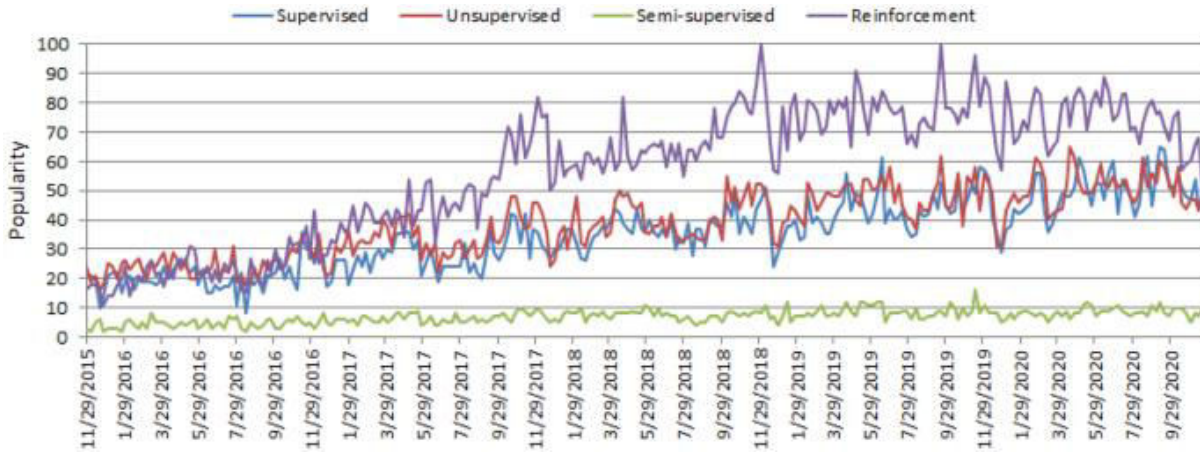


Fig.1

Generally speaking, the type and properties of the data as well as the performance of the learning algorithms determine how successful and efficient a machine learning solution is. Classification analysis, regression, data clustering, feature engineering and dimensionality reduction, association rule learning, and reinforcement learning are methods used in machine learning algorithms to efficiently construct data-driven systems. Furthermore, the artificial neural network, which is a member of a larger family of machine learning techniques, is the source of deep learning and may be used to intelligently examine data. Therefore, it can be difficult to choose a learning algorithm that is appropriate for the intended use in a certain field. The reason is that different learning algorithms have different goals, and depending on the properties of the data, even learning algorithms in the same category may provide different results. In order to apply machine learning algorithms in a variety of real-world application areas—including IoT systems, cybersecurity services, business and recommendation systems, smart cities, healthcare and COVID-19, context-aware systems, sustainable agriculture, and many more—it is crucial to comprehend the fundamentals of these algorithms. These topics are covered in brief in Section "Applications of Machine Learning."

## II. REINFORCEMENT LEARNING

Reinforcement learning (RL) is a machine learning technique that allows an agent to learn by trial and error in an interactive environment using input from its actions and experiences. The RL approach is predicated on interacting with the environment, as opposed to supervised learning, which is predicated on provided sample data or instances. The problem to be solved in reinforcement learning (RL) is defined as a Markov Decision Process (MDP) i.e., all about sequentially making decisions. An RL problem typically includes four elements such as Agent, Environment, Rewards, and Policy.

Model-based and model-free approaches are the two broad categories into which RL may be divided. The process of conducting actions and watching the outcomes, such as the next state and the immediate reward, in order to infer optimal behavior from a model of the environment is known as model-based reinforcement learning [85]. AlphaZero and AlphaGo are two instances of model-based methodologies. Conversely, a model-free method does not make use of the reward function and transition probability distribution linked to MDP. Examples of model-free algorithms are SARSA (State–Action–Reward–State–Action), Monte Carlo Control, Q-learning, and Deep Q Network. The primary distinction between model-free and model-based learning is the policy network, which is necessary for model-based RL but not for model-free. We go over the widely used RL algorithms in the sections that follow.

**Monte Carlo techniques:** Also known as Monte Carlo experiments, these computational procedures fall into a broad group and use repeated random sampling to get numerical results. The fundamental idea is to solve theoretically deterministic situations by using randomization. Monte Carlo methods are most frequently applied to three issue classes: optimization, numerical integration, and drawing from the probability distribution.

-Deep Q-learning: The fundamental process of Deep Q-Learning involves feeding the initial state into a neural network, which then outputs the Q-value of every action that might be taken. Nonetheless, Q-learning does effectively in

situations that are relatively easy to navigate. However, deep learning can be utilized as a function approximator when the number of states and actions becomes more complex.

Among the fundamental machine learning paradigms are reinforcement learning, supervised learning, and unsupervised learning. Game theory, control theory, operations analysis, information theory, simulation-based optimization, manufacturing, supply chain logistics, multi-agent systems, swarm intelligence, aircraft control, robot motion control, and many other domains can all benefit from the application of reinforcement learning (RL).

### III. ARTIFICIAL NEURAL NETWORK AND DEEP LEARNING

With representation learning, deep learning is a subset of a larger family of machine learning techniques based on artificial neural networks (ANNs). In order to learn from data, deep learning combines many processing layers, including input, hidden, and output layers, to form a computational architecture. Deep learning's primary benefit over conventional machine learning techniques is that it performs better in a number of scenarios, especially when learning from big datasets. In light of the growing volume of data, Fig. 2 illustrates the overall superiority of deep learning over machine learning. It might, however, differ based on the experimental setup and data properties.



Fig.2

Multi-layer Perceptrons (MLP), Convolutional Neural Networks (CNN, or ConvNet), and Long Short-Term Memory Recurrent Neural Networks (LSTM-RNN) are the most widely used deep learning algorithms. In the sections that follow, we go over several kinds of deep learning techniques that can be applied to create efficient data-driven models for a range of uses.

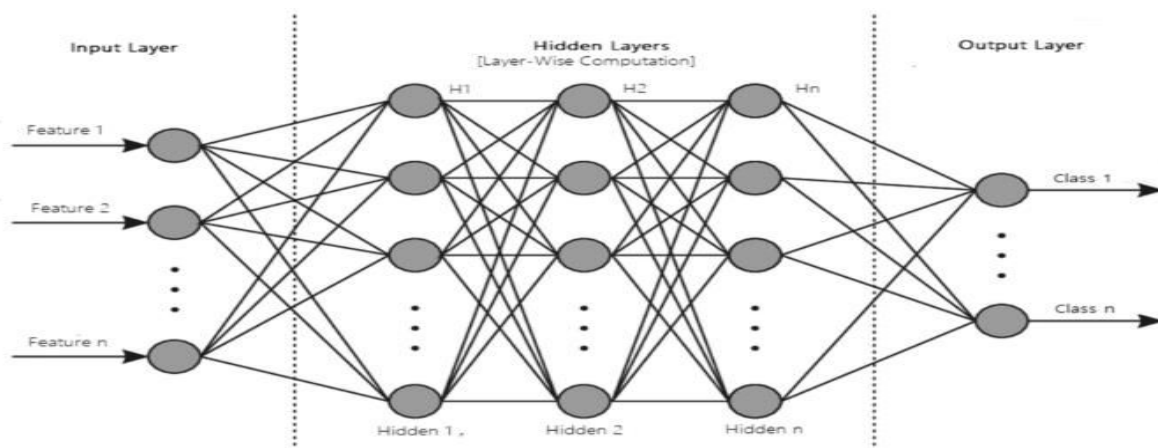


Fig.3

**MLP:** A multilayer perceptron (MLP) is the foundational architecture of deep learning, sometimes referred to as the feed-forward artificial neural network. As seen in Fig.3, a typical MLP is a fully linked network with an input layer, one or more hidden layers, and an output layer. At a specific weight, every node in one layer is connected to every node in the layer below. The most "fundamental building block" of a neural network, the "Backpropagation" approach, is used by MLP to internally modify the weight values as the model is being constructed. MLP can provide a computationally expensive model since it is sensitive to scaling features and allows for the tuning of numerous hyper parameters, including the number of hidden layers, neurons, and iterations.

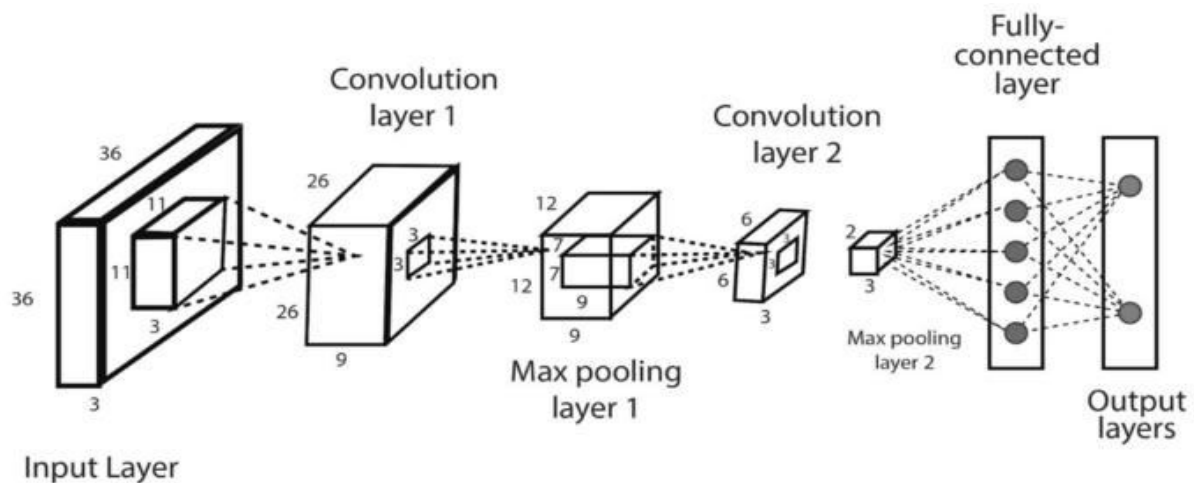


Fig.4

**CNN or ConvNet:** As illustrated in Fig.4, the convolution neural network (CNN) improves upon the architecture of the conventional ANN by including convolutional, pooling, and fully connected layers. It is generally widely utilized in a variety of fields, including image and video recognition, image processing and classification, medical image analysis, natural language processing, etc., since it capitalizes on the two-dimensional (2D) structure of the input data. CNN is thought to be more powerful than a traditional ANN because, despite its higher computing load, it has the advantage of automatically identifying the key elements without the need for human interaction. Numerous sophisticated CNN-based deep learning models, including AlexNet, Xception, Inception, Visual Geometry Group (VGG), ResNet, and others, can be applied in the field.

The artificial recurrent neural network (RNN) architecture known as long short-term memory (LSTM) is employed in the field of deep learning. Unlike typical feed-forward neural networks, LSTM incorporates feedback linkages. What sets LSTM networks apart from other traditional networks is their ability to analyze and learn sequential data, including data classification, processing, and prediction based on time series data. As a result, LSTM is frequently employed in the fields of time-series analysis, natural language processing, speech recognition, etc., and may be applied when the data is in a sequential format, such as time, sentence, etc.

There are a number of additional deep learning techniques available in the field for different applications in addition to the most popular ones covered above. For example, the self-organizing map (SOM) achieves dimensionality reduction by representing the high-dimensional data by a 2D grid map via unsupervised learning. Another popular learning method for dimensionality reduction and feature extraction in unsupervised learning tasks is the autoencoder (AE). Dimensionality reduction, classification, regression, collaborative filtering, feature learning, and topic modeling are among the applications for restricted Boltzmann machines (RBM).

Generally, a deep belief network (DBN) is made up of a backpropagation neural network (BPNN) plus basic, unsupervised networks like autoencoders or restricted Boltzmann machines (RBMs). One type of deep learning network that can produce data with properties similar to the original data input is a generative adversarial network (GAN). Because it can train deep neural networks with relatively little data—typically the re-use of a new problem with a pre-trained model—transfer learning is currently quite popular. Our previous study, Sarker et al., provides a brief

overview of these deep learning (DL) and artificial neural network (ANN) models.

Overall, we can draw the conclusion that different kinds of machine learning techniques, including classification analysis, regression, data clustering, feature selection and extraction, dimensionality reduction, association rule learning, reinforcement learning, or deep learning techniques, can be useful for different purposes depending on their capabilities. This is based on the learning techniques that were previously discussed. We go over a number of machine learning algorithm-based application areas in the section that follows.

#### IV. APPLICATIONS OF MACHINE LEARNING

Due to its ability to learn from the past and make wise decisions, machine learning is becoming more and more popular in a variety of application areas in the present Fourth Industrial Revolution (4IR). The ten most common uses of machine learning technology are outlined and discussed below.

**Predictive analytics and intelligent decision-making:** Data-driven predictive analytics is a key area of application for machine learning in intelligent decision-making. In order to forecast an unknown outcome, predictive analytics relies on identifying and taking advantage of correlations between explanatory variables and predicted variables from past occurrences. For example, detecting credit card theft in real time or identifying suspects or offenders after a crime has been committed. Machine learning algorithms can also help retailers better understand the tastes and behavior of their customers, manage inventory, prevent out-of-stock problems, and optimize warehousing and logistics in e-commerce. The field frequently uses a variety of machine learning algorithms, including artificial neural networks, decision trees, support vector machines, and others. Accurate forecasts can help nearly any organization, including government agencies, e-commerce, telecommunications, banking and financial services, healthcare, sales and marketing, transportation, social networking, and many more, make better decisions because they offer insight into the unknown.

**Cyber security and threat intelligence:** Cyber security, which is generally the process of defending networks, systems, hardware, and data against digital threats, is one of the most important aspects of Industry 4.0. In order to better detect malware in encrypted traffic, identify insider threats, predict the locations of dangerous neighborhoods online, keep people safe while browsing, or secure data in the cloud by spotting suspicious activity, machine learning has emerged as a critical cyber security technology. Clustering techniques, for example, can be used to find policy violations, cyber-anomalies, etc. Machine learning classification models that consider the influence of security parameters are helpful in detecting different kinds of intrusions or cyber attacks. On the vast volume of security datasets, a variety of deep learning-based security models can also be applied. Furthermore, the development of a rule-based security system can be greatly aided by security policy rules produced using association rule learning techniques. We may therefore conclude that the different learning strategies covered in Sect. Machine Learning Tasks and Algorithms can help cyber security experts be more proactive in effectively averting threats and cyber attacks.

**Internet of things (IoT) and smart cities:** Another crucial component of Industry 4.0 is the Internet of Things (IoT), which transforms commonplace items into smart ones by enabling data transmission and task automation without requiring human intervention. With the potential to improve nearly every aspect of our lives, including smart governance, smart homes, education, communication, transportation, retail, agriculture, health care, and business, IoT is seen as the next big thing. One of the main areas of application for IoT is smart cities, which use technology to improve city services and the quality of life for citizens. Machine learning has emerged as a key technique for Internet of Things applications since it leverages experience to identify patterns and develop models that aid in forecasting future behavior and events. Depending on the needs of the people today, machine learning techniques can be used to solve tasks like predicting traffic in smart cities, parking availability prediction, estimating the total energy usage of the citizens for a specific period, making timely and context-aware decisions for the people, etc.

**Transportation and traffic forecasting:** Transportation networks are now an essential part of any nation's economic growth. However, an excessive increase in traffic volume is occurring in a number of cities worldwide, leading to major problems such traffic jams, delays, increasing fuel costs, CO pollution, accidents, crises, and a deterioration in the standard of living in contemporary society. Thus, one essential component of a smart city is an intelligent transportation system that forecasts future traffic. The problems can be reduced with the use of machine and deep learning models for accurate traffic forecast. For instance, machine learning can help transportation businesses anticipate potential problems



that might arise on particular routes and suggest that their clients take an alternative route based on travel history and trends. In the end, by modeling and visualizing future changes, these learning-based data-driven models can enhance traffic flow, boost the use and effectiveness of sustainable modes of transportation, and minimize disruption in the real world.

**Healthcare and the COVID-19 pandemic:** Machine learning may assist in resolving diagnostic and prognostic issues in a number of medical fields, including patient management, disease prediction, medical knowledge extraction, and data regularity detection. According to the World Health Organization (WHO), coronavirus disease (COVID-19) is an infectious disease brought on by a recently identified coronavirus. In the fight against COVID-19, learning strategies have gained popularity recently. Learning techniques are applied to the COVID-19 epidemic in order to categorize high-risk patients, their mortality rate, and other abnormalities. Additionally, it can be used for disease diagnosis and treatment, COVID-19 outbreak prediction, and a deeper understanding of the virus's genesis. Researchers can predict where and when the COVID-19 virus is likely to spread with the aid of machine learning, and they may alert those areas to make the necessary preparations. In addition to offering intriguing answers to medical image processing issues, deep learning is seen as an essential method for future uses, especially in light of the COVID-19 pandemic. All things considered, machine and deep learning methods can support both intelligent clinical decision-making in the healthcare industry and the fight against the COVID-19 virus and the pandemic.

**E-commerce and product recommendations:** One of the most well-known and frequently utilized uses of machine learning is product suggestion, which is also one of the most noticeable aspects of practically every e-commerce website available today. Machine learning technology can assist businesses in analyzing their consumers' purchasing histories and making customized product suggestions for their next purchase based on their behavior and preferences. For instance, e-commerce businesses can quickly position offers and product recommendations by looking at browsing patterns and item click-through rates. Many online merchants, including Amazon, can improve inventory management, avoid out-of-stock situations, and streamline shipping and warehousing by utilizing machine learning-based predictive modeling. The capacity to collect, analyze, and apply customer data to deliver a personalized shopping experience is the key to the future of marketing and sales. Additionally, by using machine learning techniques, businesses may produce content and packages that are customized to the demands of their clients, keeping current clients while drawing in new ones.

**Image, speech, and pattern recognition:** One well-known and pervasive real-world application of machine learning is image recognition, which is able to recognize an object as a digital picture. Examples of image recognition include the ability to identify a face in an image, identify a character in an x-ray, and tag suggestions on social networking platforms like Facebook. Machine learning techniques are utilized in speech recognition, which is also quite common and usually employs linguistic and sound models, such as Google Assistant, Cortana, Siri, Alexa, etc. The automatic identification of patterns and regularities in data, such as picture analysis, is known as pattern recognition. The field makes use of a number of machine learning techniques, including feature selection, clustering, classification, and sequence labeling.

In the pre-production stage, machine learning can be used to predict crop yield, soil characteristics, irrigation needs, etc. In the production stage, it can be used to predict weather, detect diseases, detect weeds, manage soil nutrients, manage livestock, etc. In the processing stage, it can be used to estimate demand, plan production, etc.; and in the distribution stage, it can be used to manage inventory, analyze consumers, etc. Apart from these application domains, machine learning-based models can also be used in a number of other fields, including advanced engineering, bioinformatics, cheminformatics, computer networks, DNA sequence categorization, finance and economics, robotics, and many more.

## **V. CHALLENGE AND RESEARCH DIRECTIONS**

A number of research questions are raised by our investigation into machine learning algorithms for intelligent data analysis and applications. As a result, we provide an overview and discussion of the difficulties encountered, as well as possible avenues for future research.

Generally speaking, the nature and properties of the data as well as the performance of the learning algorithms determine how successful and efficient a machine learning-based solution is. Although the current cyberspace permits

the generation of a massive amount of data with very high frequency, it is not easy to gather the data in the relevant domain, such as cyber security, IoT, healthcare, and agriculture addressed in Sect. "Applications of Machine Learning." Therefore, gathering relevant data for the intended machine learning-based applications—such as smart city applications—and managing them is crucial for additional research. Therefore, in working with the real-world data, a more thorough examination of data collection techniques is required.

There are numerous machine learning methods available to evaluate data and derive insights; these are compiled in Section "Machine Learning Tasks and Algorithms." Therefore, it is difficult to choose a learning algorithm that is appropriate for the intended use. The rationale is that the results of various learning algorithms can differ based on the properties of the data. Choosing the incorrect learning algorithm could lead to unanticipated results that could reduce the model's accuracy and efficacy as well as effort. Regarding model construction, the methods covered in Sect. "Machine Learning Tasks and Algorithms". Therefore, it is difficult to choose a learning algorithm that is appropriate for the intended use. The rationale is that the results of various learning algorithms can differ based on the properties of the data [106]. Choosing the incorrect learning algorithm could lead to unanticipated results that could reduce the model's accuracy and efficacy as well as effort. In terms of model building, the techniques discussed in Sect. "Machine Learning Tasks and Algorithms" can directly be used to solve many real-world issues in diverse domains, such as cyber security, smart cities and healthcare summarized in Sect. "Applications of Machine Learning". But the mixed learning approach, An example of future work in the field could be the ensemble of methods, the modification or improvement of the current learning procedures, or the creation of new learning methods.

As a result, both the data and the learning algorithms are crucial to the final success of a machine learning-based solution and related applications. Machine learning models may become ineffective or yield reduced accuracy if the data is difficult to learn from, such as non-representative, low-quality, irrelevant features, or insufficient quantity for training. Therefore, for a machine learning-based solution and ultimately the development of intelligent applications, efficiently processing the data and managing the many learning algorithms are crucial.

## VI. CONCLUSION

In this study, we have conducted a comprehensive assessment of machine learning techniques for intelligent data analysis and applications. In line with our goal, we have briefly discussed the various ways that machine learning techniques might be used to address a variety of real-world issues. Both the data and the effectiveness of the learning algorithms are necessary for a machine learning model to be successful.

The collected real-world data and application-specific knowledge must be used to teach the advanced learning algorithms before the system can facilitate intelligent decision-making. They also discussed some well-known application areas to show how machine learning methods can be used to solve a range of real-world issues. Our firm has wrapped up by reviewing and discussing the challenges faced as well as potential directions for further study and advancement in the area. As a result, the aforementioned problems raise important research questions in the field that need practical solutions in a range of application domains.

All things considered, we think that our research on machine learning-based solutions points in a positive direction and can serve as a technical reference manual for future studies and applications for professionals in academia and business as well as decision-makers.

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