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NUCLEUS RESEARCH

AN INSIGHT INTO CONVOLUTIONAL NEURAL NETWORKS

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THE BOTTOM LINE

Cloud-based services have opened new doors for automation by leveraging deep learning in business. The recent availability of mass data training sets and growing computational power has allowed many industries to expand operational processes. The application of deep learning subgroups, such as convolutional neural networks (CNN), is becoming widely applicable in addressing business needs through a self-learning model. The result is the rapid growth of emerging cloud-based companies that are focused on providing artificial intelligence (AI) assistance as a service to enterprise-level organizations. CNN adoption has led to improved forecasting prediction accuracy by 30 percent and doubled the rate at which enhanced forecasting models are produced. Users can leverage improvements in image classification to drive time savings and prediction accuracy with CNN solutions.

OVERVIEW

Deep learning has recently been a major topic of interest in the media today. However, there is a large disconnect between what the public perceives as deep learning and what it is in actuality. When mentioning AI, most would refer to the capabilities of machine learning (ML), which leverages surface level data to produce a desired output without human intervention. However, the full capacity of AI is significantly deeper than that. Deep learning refers to the use of multiple algorithmic layers to identify patterns in big data. CNN's, being a subset of deep learning, is gaining significant traction in many business applications due to its ability to distinguish visual imagery in massive data sets. Its application has been widely seen in the healthcare, autonomous vehicle, and e-commerce markets, while increasingly seeing adoption in general business use cases as well.

UNDERSTANDING CONVOLUTIONAL NEURAL NETWORKS

The concept of deep learning is often met with high enthusiasm but considerable misunderstanding and skepticism. The common delusion associated with the idea is that it is purposed to handle mundane tasks, simplifying the lives of its users. However, deep learning has already proven to be applicable across many areas of modern innovation and business processes. To understand the vast benefits associated with convolutional learning one must first grasp the basics.

The human brain is constantly being bombarded with sensory information received from the environment. However, it can exclude "noise" and distinguish what is most important. This is possible due to neurons found in the brain, which process external stimuli and focus on certain environmental features that are the most relevant. Perceptrons, inspired by neurons, are binary classifiers which categorize massive data under a set of labels. As a result, the algorithm is able to recognize, store and discriminate data, giving them a pivotal role in the fundamental processes of deep learning.

CNN models are able extract distinct features from massive data sets through a series of image filtering techniques. Data sets are introduced to a perceptron through its input layer, which is assigned a weight to prioritize information entry before being computed in a hidden layer. Where CNN's contrast from most other deep learning subgroups is in its multiple filter configuration used to identify patterns in data. Computations occur in the convolutional layer, which scans a grid for basic features such as lines and colors. The 3x3

filter does this throughout the input matrix until the full image is analyzed. A subsequent pooling layer simplifies the data by reducing the number of parameters before it is passed on into the output layer. The results in the output layer are compared with desired results and an error is calculated. The error is passed back into the algorithm where changes in weights act to improve the accuracy of future computations. CNN's have been shown to simplify complex operational tasks with an improvement in time and reduction in required personnel. Some common industry applications include bio-imaging, self-driving technology, and product demand forecasting.

THE CHALLENGES

Nucleus identified the main challenges faced by company's when using CNN's: overfitting, exploding gradients, and class imbalances.

A major barrier for CNN's to overcome is inconsistent error calculations between the training set and the testing set, known as overfitting. When the algorithm is trained well, it can effectively identify features it was conditioned to detect in the testing set. This often leads to low error margins and is represented as an ideal model. However, over-conditioning during the training phase limits the algorithms' ability to classify new data that it has not previously encountered. The issue is exacerbated when reconfiguring input weights to reduce already low error rates, leading the algorithm to continually overlook the same mistakes. Conversely, a significant amount of new data into the model can lead to large error margins which can result in an exploding gradient.

CNN's must continue to adapt and update to improve computational accuracy; however, inefficient learning is often caused by an exploding gradient. Differences in results between actual and calculated outputs are used to update the network through the reconfiguration of weights to minimize future error. Significant variation in these errors can lead to excessively high weight changes, ultimately overwhelming the system and ceasing calculations. Mitigating the risk of an exploding gradient occurring can be done by ensuring data fed into the network is pre-processed to ensure the potential error stays within acceptable bounds.

Massive data volumes continue to improve deep learning model performance, but the prevalence of class imbalances may lead to unfavorable output results. A class imbalance is the result of differences in the size of integrated data between input layer nodes, leading the algorithm to form a bias towards the larger sample. The disproportion in results causes inaccuracies in calculating error, leading the algorithm to assign incorrect weights during

backpropagation. Minority classes are underrepresented and therefore hold an inaccurately low level of importance in algorithm processing.

VENDOR USE CASES

GE HEALTHCARE - AIR RECON DL

GE Healthcare is an industry leading medical technology company with a focus on providing intelligent devices, data analytics, applications, and services. The vendor has made significant strides towards offering deep learning as one of its core competencies with the launching of AIR Recon DL, a CNN-based algorithm designed to improve SNR and image sharpness. The solution was embedded into the Edison intelligence platform which is designed to integrate and analyze data from disparate sources allowing users to improve analytic capabilities, patient outcomes and access to care.

This New England based company provides magnetic resonance imaging (MRI), positron emission tomography (PET) and computerized tomography (CT) services to patients in more than 30 locations. The company aimed to improve the operational efficiency of its MRI protocol using a CNN solution. Factors that were considered when choosing a solution included its ability to produce high-quality images and reduce patient wait times. The company noted that the majority of patient wait time was spent in an MRI machine largely due to radiologists working towards optimizing the signal-to-noise ratio in the final image.

The company selected Air Recon DL due to its comprehensive data set that included over 10,000 images already processed during the learning phase. Since deployment, the company has realized a 30 percent reduction in scanning time primarily due to automated noise reduction features, typically done manually by radiologists. The company also reported improved resolution, shorter scan duration and a better signal to noise ratio (SNR) as major benefits post-software adoption. The solution is further able to identify over 100,000 unique recognition patterns, allowing it to create high resolution images by displaying only ideal object features to providers.

NASA - DEEPSAT

The National Aeronautics and Space Administration (NASA) is a branch of the U.S. federal government and is responsible for the civilian space program as well as aeronautics and

space research. The company relies on receiving accurate land surface imagery to understand the impact of global warming on crop yields, vegetation, and glacier changes. However, high variability in satellite data and a lack of comprehensive training sets has made it difficult to reach reliable conclusions. NASA attempted to overcome these barriers using commercial software but were quickly faced with limitations in scalability due to their vast region of study; being the earth.

The company decided to develop a CNN solution within its Earth Science and Carbon Monitoring System to better track changing landscapes at optimal resolutions. DeepSat, a neural network algorithm purposed for satellite image classification and segmentation, leveraged the use of the vendors massive training set (SATnet) to address SNR limitations. This was done by leveraging over 330,000 image scenes from across the continental U.S., further improving the amount of training data used during the solutions learning phase. As a result of NASA's increased data input size, it significantly reduced its SNR and enhanced image resolution. Dataset classification improved to a 97.75 percent accuracy, outperforming 11 percent of industry leading object detection algorithms.

AMAZON - FORECASTING

Amazon has recently deployed Amazon Forecast, an algorithm based on time series, historical data, and other personalized factors, to improve its demand forecasting capabilities. Recurring issues such as frequent price changes, differences between local versus national demand, and products with varying selling rates has left the company unable to predict future demand for goods consistently and accurately. The vendors existing statistical forecasting models are primarily geared towards the buying patterns of seasonal products and are largely ineffective when applied to less predictive merchandise. Inadequate inventory levels are a common problem faced by end-users with the vendor offering limited solutions to overcome this obstacle.

A decision was made to integrate a forecasting platform that is solely geared towards accurately detecting consumer buying patterns. A CNN solution centered on a sophisticated deep learning network was incorporated into Amazon's existing forecasting model, leading to an improvement in prediction accuracy by 30 percent. Proactive inventory tracking was also a major benefit for end-users as the solution was able to train models twice as fast compared to previous algorithms. Lead indicators of demand such as pre-order information, product page visits and price changes were among the many elements considered by the solution to accurately forecast future buying habits. The solution will

equip end-users with the ability to predict future demand more accurately and therefore be prepared to satisfy it.

CONCLUSION

CNN's have seen widespread adoption across many industries, sparking a new wave of technological advancement. Newly found access to large datasets across varying disciplines has equipped users with the tools to simplify time-consuming tasks while excluding the operational inefficiencies resulting from human error. Users can focus on high value tasks that are geared towards product advancement, such as CNN driven demand forecasting and costing models. Cloud-based services are becoming an integral part of CNN adoption as the expanding availability of microservices satisfy specific business needs across many industries. Nucleus expects this growth to continue as deep learning capabilities redefine how modern business is conducted.