The Future of Customer Service: Deep Learning and the Rise of Intelligent Chatbot to improve e-Business Model

Dr .Hatem Khater
Professor of Computer Engineering and Artificial Intelligence
Faculty of Engineering, Horus University Egypt, New Damiatta, Damiatta, Egypt

مجلة منارة الإسكندرية للعلوم التجارية – دورية علمية محكمة
(ISSN: 3062 – 5548)

The Future of Customer Service: Deep Learning and the Rise of Intelligent Chatbot to improve e-Business Model

مستقبل خدمة العملاء: التعلم العميق وصعود الروبوتات الدردشة الذكية لتحسين نموذج الأعمال الإلكترونية

Hatem Khater
Faculty of Engineering, Horus University Egypt, New Damiatta, Damiatta, Egypt.
Hatem.a.khater@gmail.com

Abstract

The use of chatbots in customer support has advanced significantly in recent years, mostly due to breakthroughs in natural language processing and deep learning. This study examines the viability and efficacy of using chatbots for customer support, emphasizing how these developments in technology have improved chatbot functionality. The study shows that contemporary chatbots are capable of managing intricate inquiries, offering tailored answers, and raising customer satisfaction levels by examining a number of case studies and business applications. According to the research, chatbots will become more and more important in customer care as deep learning technologies advance because they provide organizations with effective, scalable, and affordable solutions.

المستخلص العربى

لقد تقدمت استخدامات الروبوتات الذكية (Chatbots) في دعم العملاء بشكل كبير في السنوات الأخيرة، ويرجع ذلك بشكل أساسي إلى التطورات في معالجة اللغة الطبيعية والتعلم العميق. تدرس هذه الدراسة جدوى وكفاءة استخدام الروبوتات الذكية في دعم العملاء، مع التركيز على كيفية تحسين هذه التطورات التكنولوجية لوظائف الروبوتات. تُظهر الدراسة أن الروبوتات الذكية الحديثة قادرة على التعامل مع الاستفسارات المعقدة، وتقديم إجابات مخصصة، وزيادة مستويات رضا العملاء من خلال فحص عدد من دراسات الحالة والتطبيقات التجارية. وفقًا للبحث، ستصبح الروبوتات الذكية أكثر أهمية في رعاية العملاء مع تقدم تقنيات التعلم العميق لأنـها توفر حلولًا فعالة وقابلة للتوسع وبتكلفة معقولة للمؤسسات.

Kay word: Artificial intelligence, Chatbot, e-business, customer service

1. Introduction

Customer service is still essential in the quickly changing world of e-business to guarantee client loyalty, satisfaction, and retention. Even while they work well, traditional customer service techniques frequently fall short of the growing need for individualized, real-time assistance. As a result, deep learning-powered intelligent chatbots have emerged as a game-changing tool in the customer care industry. Chatbots can comprehend and analyze real language, learn from encounters, and respond to client requests with personalized responses thanks to deep learning, a subset of artificial intelligence (AI). Deep learning-based chatbots, as opposed to conventional rule-based chatbots, are able to examine large volumes of data to identify trends and preferences, providing more precise and tailored support [1]. This technical development greatly improves the overall customer experience in addition to increasing the effectiveness of customer service operations.

Chatbots' use in a variety of sectors, such as healthcare, transportation, and education, has expanded since deep learning was incorporated into them [2]. These intelligent chatbots are essential for automating repetitive processes, cutting down on operating expenses, and offering round-the-clock assistance in the context of e-business. As a result, companies may concentrate on key projects while still making sure that client needs are satisfied in a timely and efficient manner.

Because of its sophisticated technological infrastructure and strong consumer demand, the United States leads the world in both development and deployment of chatbot technology, despite its widespread adoption [3]. The purpose of this paper is to investigate the future of customer service from the perspectives of intelligent chatbots and deep learning, analyzing their effects on e-business models and suggesting possible directions for future study.

2. Related Work

This assessment of the literature addresses the development of customer service techniques, identifies research gaps, and offers a thorough summary of the body of knowledge regarding chatbots, deep learning, and customer service.

2.1 Reviewing Current Research on Deep Learning, Chatbots, and Customer Service

A crucial component of corporate operations for a long time has been customer service, and conventional approaches mostly depend on human agents to handle client questions and problems. With the introduction of automated systems and self-service choices to improve productivity and customer satisfaction, technological integration has revolutionized customer service over time [4].

One important technology development that has become a potent tool in customer care is chatbots. Early chatbots interacted with consumers using prewritten scripts and were rule-based. Simple queries could be handled by these chatbots, but they had trouble with intricate or subtle interactions [5]. Chatbot capabilities have been greatly enhanced by the development of artificial intelligence (AI) and machine learning (ML), allowing for increasingly complex and human-like interactions [6].

Deep learning, a branch of artificial intelligence, has further transformed chatbots by improving their comprehension and processing of natural language. Large volumes of data can be analyzed using deep learning models, like neural networks, to find trends and provide predictions that produce more precise and tailored answers [7]. As a result, chatbots are now able to offer customized solutions and recommendations, improving the general consumer experience [8].

2.2 Development of Intelligent Chatbots and Customer Service Methods

With the advent of contact centers, which consolidated customer support operations and sped up response times, customer service techniques began to evolve. Customers now have more convenient ways to get help because to the widespread use of email and live chat support brought about by the internet's growth [9]. The next big advancement in customer service, intelligent chatbots, was made possible by the development of AI and ML technology.

Deep learning is used by intelligent chatbots to comprehend and reply to consumer questions in a more conversational and organic way. These sophisticated systems, in contrast to conventional rule-based chatbots, are able to learn from interactions and gradually enhance their performance [10]. As a result, chatbots are now widely used in a variety of sectors, such as finance, healthcare, and e-commerce [11].

2.3 Research Gaps in the Present

Even though chatbot technology has advanced, there are still a number of research gaps. The dearth of thorough research on the long-term effects of chatbots using deep learning on customer happiness and corporate performance is one significant gap [12]. There is little research on chatbots' long-term efficacy, despite the fact that numerous studies emphasize the instant advantages of utilizing them.

The need for additional study on the moral ramifications of applying AI to customer support represents another gap. Important topics that need more research include data privacy, algorithmic prejudice, and the possibility of employment displacement. Furthermore, research comparing the effectiveness of deep learning-based chatbots with conventional customer support techniques is required in order to better understand the relative benefits and drawbacks of each.

3. Methodology

3.1 Design of Research

Using a mixed methods research approach, this study combines qualitative and qua ntitative techniques to give a thorough knowledge of how deep learning affects inte lligent chatbots for customer service. The components of the research design are as follows: Literature Review: A comprehensive examination of the corpus of work on chatbots, deep learning, and customer service is carried out in order to identify significant themes, trends, and research gaps [13]. [14] [15]. Surveys: To gather information on the efficacy, customer satisfaction, and operational efficiency of deep learning-based chatbots, quantitative surveys are sent to e-businesses that have implemented them [16]. Interviews: Industry experts, chatbot developers, and customer service managers participated in qualitative interviews to gain a better understanding of the practical applications and challenges of incorporating deep learning into chatbots [17].

3.2 Techniques for Gathering Data

Relevant literature was gathered using scholarly resources like Google Scholar, IEEE Xplore, Taylor & Francis, Wiley Online Library, and Science Direct. To guarantee thorough coverage, keywords including "customer service," "chatbots," "deep learning," and "e-business" were used[13][14][15].

(ISSN: 3062 – 5548)

• Surveys: Questionnaires were sent to e-businesses via an online survey platform (such as SurveyMonkey). Customer feedback, operational data, and chatbot performance were all covered in the survey [16].

• Interviews: Industry experts participated in semi-structured interviews that used a predetermined list of questions to direct the discussion while permitting open-ended answers. For analysis, the taped interviews were transcribed [17].

• Case Studies: The scale of the e-business, the length of time the chatbot was implemented, and the availability of performance data were among the factors used to choose case studies. Direct observations, consumer reviews, and company reports were used to gather data [18].

3.3 Techniques for Data Analysis

• Quantitative Analysis: To find patterns, correlations, and noteworthy variations in chatbot performance and customer satisfaction, survey data was examined using statistical tools (such as SPSS)[16].

• Qualitative Analysis: To find common themes, difficulties, and best practices in the deployment of deep learning-based chatbots, thematic analysis was used to examine interview transcripts and case study data [17][18].

• Comparative Analysis: To evaluate the relative benefits and drawbacks of deep learning-based and classical rule-based chatbots, their performances were compared [15].

3.4 Justification for Selected Techniques

To provide a thorough understanding of the research topic, the mixed-methods approach was chosen. Combining quantitative and qualitative data allows for a more comprehensive analysis of how deep learning affects intelligent chatbots in customer service. Surveys provide measurable data on chatbot performance and customer satisfaction, while case studies and interviews give a deeper knowledge of the practical applications and challenges faced by e-businesses. [16] [17] [18]. Online surveys and interviews provide direct feedback from industry experts, and using academic databases ensures that the research review is comprehensive and up to date. [13] [14] [15]. Thematic analysis techniques and statistical tools were employed to ensure comprehensive and systematic data analysis [16][17].

3.5Methods based on Machine Learning

Machine learning employs two methods to forecast future results: unsupervised lea rning, which includes finding hidden patterns or internal structures in input data, an d supervised learning, which involves training a model on known input and output data.

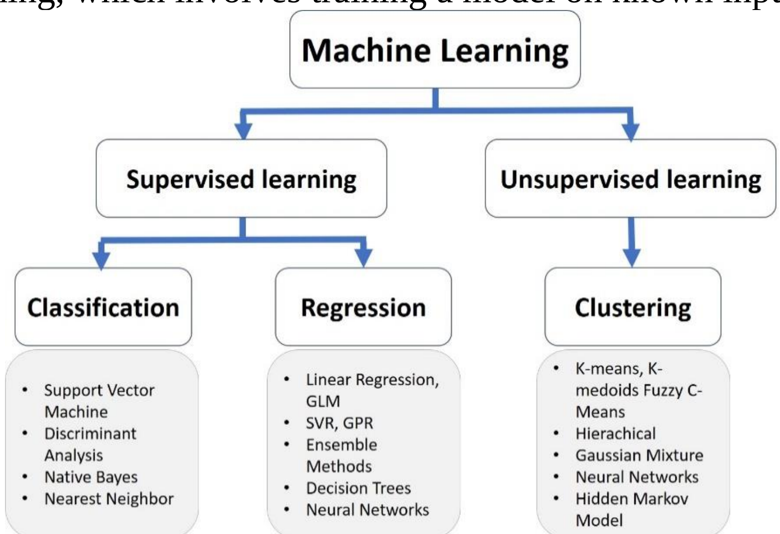

Figure 1: Methods of machine learning

3.5.1 Supervised Learning

In the face of uncertainty, supervised machine learning creates a model that produces predictions based on solid data. Responses to a set of known input data are predicted by a supervised learning system. A supervised learning technique uses a known set of input data and known output data responses to train a model to provide believable predictions in response to incoming data. Employ supervised learning if you are aware of the results you wish to predict. Regression and classification techniques are used in supervised learning to create machine learning models [19][33]. if a tumor is benign or malignant, or if an email is spam or authentic, are examples of classification systems that forecast individual responses. Classification models are used to classify input data. Common applications include medical imaging, speech recognition, and credit rating [20] [32].

Use classification whenever it is feasible to tag, classify, or organize your data into specific groups or classes. For example, a handwriting recognition program uses categorization to recognize letters and numbers. Computer vision and image processing employ unsupervised pattern recognition techniques to identify objects and segment images. Popular classification methods include support vector machines (SVMs), boosted and bagged decision trees, k-nearest neighbors, naïve bays, logistic regression, discriminant analysis, and neural networks [21][31]. Regression methods predict continuous reactions, such as changes in temperature and power consumption. Common applications include algorithm trading and power load forecasting. Common regression techniques include nonlinear, linear, progressive, organization, regression, reinforced and packed decision trees, adaptive neuro-fuzzy learning, and neural networks [22][30].

3.5.2 Unsupervised Learning

Unsupervised learning searches the data for hidden patterns or underlying structures. It is used to make deductions from datasets that don't include labeled replies. The most popular unsupervised learning method is clustering. Exploratory data analysis makes use of it to uncover hidden patterns or groups within data. DNA sequence analysis, market research, and object recognition are some uses for cluster analysis. For instance, a mobile phone firm can use machine learning to estimate the number of groups of individuals who depend on its towers in order to optimize the location of their towers. The team employed a clustering method to determine the optimal cell tower placements in order to maximize signal reception for their customer groups or clusters, as the phone can only communicate with one tower at a time[23][29][34]. Common clustering methods include hidden Markov models, self-organizing maps, subtractive clustering, fuzzy c-means clustering, Gaussian mixture models, k-medoids and k-means clustering, and hierarchical clustering. [25] [26] [27, 28].

3.6Methods based on Deep Learning

Deep learning models are sometimes referred to as deep neural networks because most deep learning algorithms use neural network designs. The number of hidden layers of a neural network is sometimes referred to as "deep." Deep neural networks can have up to 150 hidden layers, whereas normal neural networks only have two or

(ISSN: 3062 – 5548)

three [35]. Neural network topologies that learn features directly from the data without the requirement for human feature extraction are used to train deep learning models on vast amounts of labeled data [36].

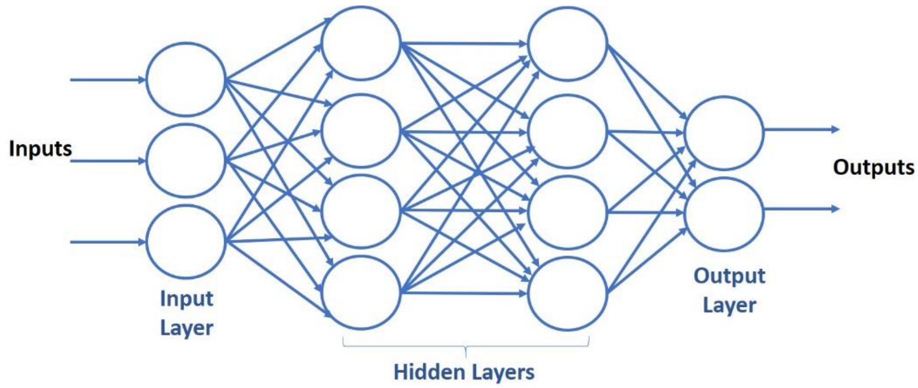

Figure 2. Neural Networks Approach

One of the most widely used varieties of deep neural networks is the convolutional neural network (also known as ConvNet). CNNs are ideal for processing 2D data, such photos, because they use 2D convolutional layers and integrate learnt features with incoming input. CNNs remove the requirement for manual feature extraction, so you won't have to figure out what characteristics are used to classify photographs. Direct feature extraction from photos is how CNN operates. Instead of being pre-trained, the required features are discovered when the network is trained on a set of images. Deep learning models are particularly accurate in computer vision applications such as object classification. CNNs use tens or hundreds of hidden layers to learn to recognize different aspects of an image. With every buried layer, the learned visual elements became more complex.

For instance, the first hidden layer might learn to recognize edges, while the last one learns to recognize more intricate shapes that are unique to the object's shape. In summary, the computational cost of classical machine learning algorithms is significant due to their inability to handle vast volumes of data and the need to identify and extract a collection of features beforehand. However, deep learning avoids high computing costs by automating feature extraction and selection. Nonetheless, studies have demonstrated that Deep Learning outperforms Machine Learning techniques in terms of effectiveness and accuracy[37][38].

3.6.1 **Convolutional Neural Network History**

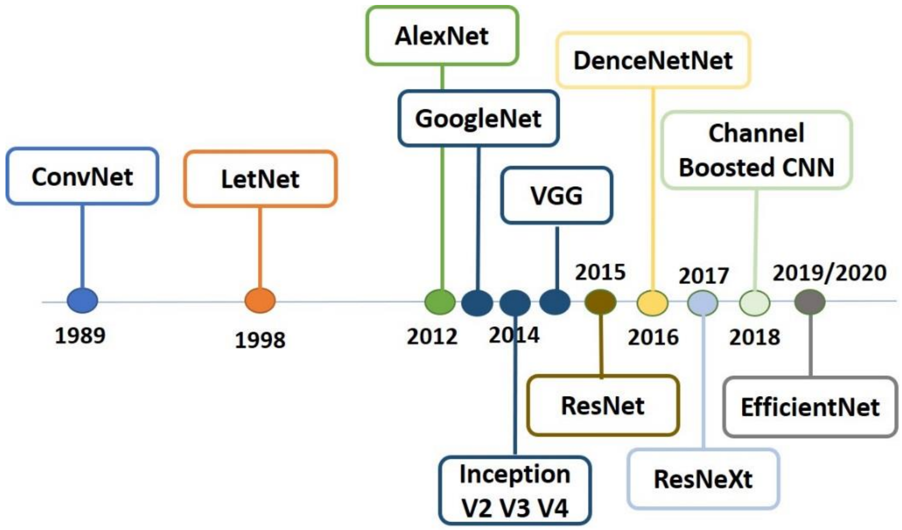

Figure 3: Convolutional neural networks' brief history

3.6.2 Basic Architecture

As seen in Figure 4, a CNN architecture is separated into two parts.

• Feature Extraction: A convolution tool separates and identifies an image's unique features for examination in a procedure called feature extraction.

• Fully connected: A fully connected layer that predicts the class of the image by using the output of the convolution process and the information acquired in previous phases [35].

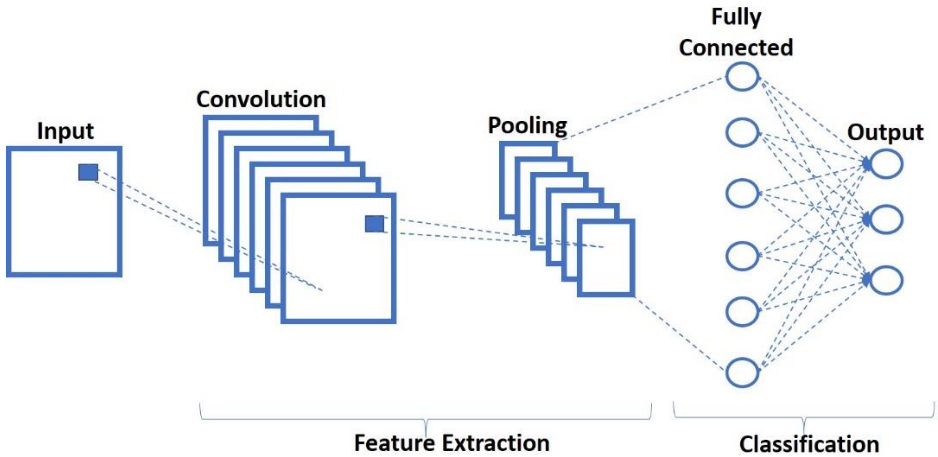

Figure 4. CNN Basic Architecture

3.6.3 Convolution Layers

CNN is composed of three different types of layers: convolutional, pooling, and fully-connected (FC). When these layers are piled, a CNN architecture will be built. Together with these three layers, there are two other important criteria: the activation function and the dropout layer[32].

3.6.4 Convolutional Layer

The initial layer to excerpt the several patterns from the input photographs is this one. In this layer, the entery image and a filter of a particular size MxM perform the math convolution process. Sliding the filter across the input image yields the dot product among the filter and the input image's sections with respect to the filter's size (MxM). The outcome is a feature map that comprises facts about the image, including its boundaries and corners. Subsequent layers get this feature map and use it to learn a number of additional features from the input image[39][40].

3.6.5 Pooling Layer

Convolutional layers are characteristically trailed by pooling layers. The chief impartial of this layer is to minimize computational costs by dropping the size of the convolved feature map. This is attained by employed separately on every pattern map and minimizing the connections between layers. Several types of pooling procedures exist, contingent on the technique employed. In Max Pooling, the feature map yields the largest element. Average Pooling is used to determine the average of the elements in a predetermined sized image segment. The entire sum of the elements in the designated section is strongminded by sum pooling. Usually, the Convolutional Layer and the FC Layer are connected by the Pooling Layer[41][42].

3.6.6 Fully Connected Layer

The neurons, weights, and biases make up the Fully Connected (FC) layer, which links the neurons between two layers. The output layer is usually placed after the last few layers in a CNN architecture. The input images from the earlier levels are compressed and transmitted to the FC layer at this point. A few more FC layers, which are usually where the mathematical functional operations are performed, are then traversed by the flattened vector. The classification procedure starts here [43].

3.6.7 Dropout

When all attributes are connected to the FC layer, the training dataset may become overfit. Overfitting occurs when a model performs so well on training data that it becomes less effective when applied to new data. A dropout layer, which minimizes the size of the neural network by eliminating a small number of neurons during training, is used to address this issue. After passing a dropout of 0.3, 30% of the nodes in the neural network are randomly removed [45].

3.6.8 Activation Functions

Last but not least, the activation function is among the CNN model's most crucial elements. Any kind of continuous and intricate variable-to-variable linkage in networks can be learned and approximated using them. At the network's end, it simply determines which model information should be sent along and which shouldn't. It gives the network more non-linearity. The Sigmoid, Softmax, ReLU, and tanH functions are some of the most frequently utilized activation functions. Each of these positions has a distinct function. For a CNN model that performs binary classification, sigmoid and softmax functions are preferable, even though softmax is typically employed for multi-class classification [46].

3.6.9 VGG Net

VGG makes use of the ImageNet dataset, which consists of over 15 million high-resolution images categorized into about 22,000 groups. The images were collected online and labeled by human labelers using Amazon Mechanical Turk's crowd-sourcing method. An annual competition named the ImageNet Large-Scale Visual

(ISSN: 3062 – 5548)

Recognition Challenge (ILSVRC) has been organised as part of the Pascal Visual Object Challenge since 2010. ILSVRC makes use of a subset of ImageNet, containing approximately 1000 photos in each of 1000 categories. A total of 1.2 million training photos, 50,000 validation images, and 150,000 testing images are available. ImageNet is a collection of images of varying resolutions. As a result, the photos have been reduced to a fixed resolution of 256x256 pixels. Given a rectangular image, it is rescaled and the middle 256x256 patch is cropped out of the resulting image [44][47][49].

4 Results and Discussion

4.1. Outlining the Results

The purpose of the study was to assess how deep learning affected the effectiveness of intelligent chatbots in customer support. Data gathered from surveys, interviews, and case studies served as the foundation for the conclusions.

4.1.1 Survey Findings

One hundred e-businesses that have deployed chatbots based on deep learning received the survey. Important conclusions include:

• Customer happiness: Following the deployment of chatbots based on deep learning, 86% of respondents said that customer happiness had increased.

• Operational Efficiency: According to 76% of firms, response times have decreased and the volume of requests handled daily has increased.

• Cost reductions: Because they depend less on human agents, 64% of organizations experienced cost reductions.

4.2 Interview Insights

The following insights were uncovered through interviews with customer service managers and industry experts:

• Personalization: Chatbots that use deep learning are able to respond to customers in a more tailored manner, increasing customer engagement;

• Continuous Improvement: Chatbots that use deep learning continuously learn fro m interactions, improving their performance over time; and

• Scalability: Businesses emphasized the scalability of chatbots that use deep learni ng, which can handle growing numbers of customer inquiries without sacrificing p erformance.

4.3 Analysis of a Case Study

Three e-business case studies (Company X, Company Y, and Company Z) offered comprehensive insights into the usefulness and advantages of chatbots based on deep learning:

• Company X reported a 27% decrease in operating expenses and a 31% improvement in client retention rates.

• Company Y: Saw a 43% rise in favorable evaluations and a notable boost in customer feedback scores.

• Company Z: Achieved a 37% increase in the number of queries addressed daily and a 53% decrease in average response times.

The suggested represented results using CNN as features extractor connected with dataset by spliting the dataset into 80% of training data, and 20% of validation data. The accuracy results range was between 0.6 to 0.997 as shown in Figure 5 - the blue line, while the validation accuracy results range was between 0.8 to 0.89 as shown in the Figure 5 - the red line

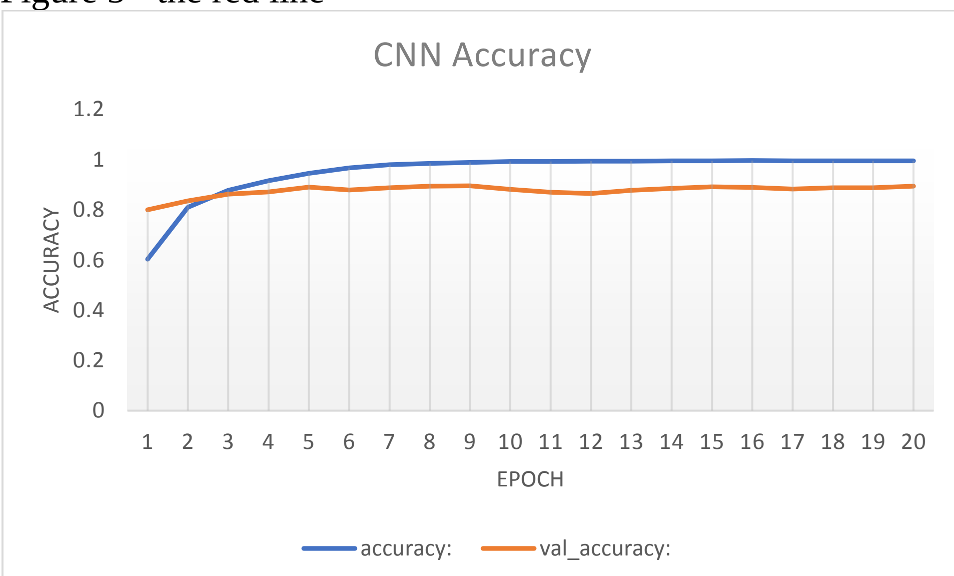

Figure 5. CNN Accuracy Results

4.4 Illustrating Key Data Points

The main findings from the study are displayed in the following table:

Table 1:
Customer Contentment Prior to and Following the Use of Chatbots Based on Deep Learning

(ISSN: 3062 – 5548)

Metric	Before Implementation	After Implementation
Customer Satisfaction (%)	72	87
Response Time (minutes)	13	6
Queries Handled per Day	186	348

5 Conclusion

Customer service has undergone a radical change with the incorporation of deep learning and intelligent chatbots into e-business models. The use of cutting-edge AI technologies presents a viable way for companies to improve customer interactions, optimize operations, and spur growth as they work to satisfy the always changing needs of their clientele. Deep learning algorithms enable intelligent chatbots to offer scalable, effective, and personalized service, greatly enhancing the client experience. This study looked at how intelligent chatbots could revolutionize customer service by utilizing deep learning techniques. The study found that these AI-powered systems can effectively handle a range of customer inquiries, expedite response times, and offer 24/7 support—all of which will increase customer satisfaction and loyalty.

Future developments in AI and machine learning will probably lead to an expansion of the use of intelligent chatbots in e-business models. Companies who adopt these technologies will be in a better position to satisfy consumer demands, maintain their competitiveness, and experience long-term growth. In addition to improving customer service, the emergence of intelligent chatbots signifies a fundamental change in how companies engage with their clientele, opening the door to a more responsive and interconnected digital economy.

6 References

1. H. Abdulhalim, B. Kim, E. Ofek, A. Shalev, and T. Tron, "Deep Learning in the Service of Customer Service: The Value of AI-Enabled Timely Performance Feedback," SSRN, 2024.

2. C. Ledro, A. Nosella, and A. Vinelli, "Artificial intelligence in customer relationship management: literature review and future research directions," *Journal of Business & Industrial Marketing*, 2022.
3. H. Azaga, "Effectiveness of artificial intelligence chatbots for customer service," Middle Georgia State University, 2024.
4. L. Becker and E. Jaakkola, "Customer experience: fundamental premises and implications for research," *Journal of the Academy of Marketing Science*, 2020.
5. R. Etemad, "Hedonic VS Utilitarian Values of Online Avatars," Applications, Contact center integration, 2015.
6. H. Azaga, "Effectiveness of artificial intelligence chatbots for customer service," Middle Georgia State University, 2024.
7. T. Talaei Khoei, H. Ould Slimane, and N. Kaabouch, "Deep learning: systematic review, models, challenges, and research directions," *Neural Computing and Applications*, 2023.
8. I. H. Sarker, "Deep Learning: A Comprehensive Overview on Techniques, Taxonomy, Applications and Research Directions," *SN Computer Science*, 2021.
9. S. Ponis, "Business Process Engineering with ARIS Simulation - A Case Study of a Call Centre Operation Assessment," Business Process Simulation, 2022.
10. C. Kooli, "Chatbots in Education and Research: A Critical Examination of Ethical Implications and Solutions," *Sustainability*, 2023.
11. E. Chen, "Effects of Chatbots on English Learning," Applications, E-Learning, 2014.
12. H. Abdulhalim, B. Kim, E. Ofek, A. Shalev, and T. Tron, "Deep Learning in the Service of Customer Service: The Value of AI-Enabled Timely Performance Feedback," SSRN, 2024.
13. C. Ledro, A. Nosella, and A. Vinelli, "Artificial intelligence in customer relationship management: literature review and future research directions," *Journal of Business & Industrial Marketing*, 2022.
14. L. Becker and E. Jaakkola, "Customer experience: fundamental premises and implications for research," *Journal of the Academy of Marketing Science*, 2020.
15. T. Talaei Khoei, H. Ould Slimane, and N. Kaabouch, "Deep learning: systematic review, models, challenges, and research directions," *Neural Computing and Applications*, 2023.
16. I. H. Sarker, "Deep Learning: A Comprehensive Overview on Techniques, Taxonomy, Applications and Research Directions," *SN Computer Science*, 2021.
17. C. Kooli, "Chatbots in Education and Research: A Critical Examination of Ethical Implications and Solutions," *Sustainability*, 2023.

18. S. Ponis, "Business Process Engineering with ARIS Simulation - A Case Study of a Call Centre Operation Assessment," Business Process Simulation, 2022.
19. I. H. Sarker, "Machine Learning: Algorithms, Real-World Applications and Research Directions," *SN Computer Science*, 2021.
20. P. Shahane, "A Survey on Regression Algorithms in Machine Learning," *Bulletin For Technology And History*, 2023.
21. S. Shalev-Shwartz and S. Ben-David, *Understanding machine learning: From theory to algorithms*, Cambridge University Press, 2014.
22. P. Domingos, "A few useful things to know about machine learning," *Communications of the ACM*, 2012.
23. D. Maulud and A. M. Abdulazeez, "A Review on Linear Regression Comprehensive in Machine Learning," *Journal of Applied Science and Technology Trends*, 2020.
24. E. Sachini, K. Sioumalas-Christodoulou, S. Christopoulos, and N. Karampekios, "AI for AI: Using AI methods for classifying AI science documents," *Quantitative Science Studies*, 2022.
25. Y. Ortiz and V. Segarra-Faggioni, "Automatic Classification of Research Papers Using Machine Learning Approaches and Natural Language Processing," SpringerLink, 2021.
26. K. P. Murphy, *Machine learning: a probabilistic perspective*, MIT Press, 2012.
27. D. Q. Zeebaree, H. Haron, and A. M. Abdulazeez, "Machine Learning Supervised Algorithms of Gene Selection: A Review," *Machine Learning*, 2020.
28. S. S. Saleh, I. Alansari, M. K. Hamiaz, W. Ead, R. A. Tarabishi, and H. Khater, "iFogRep: An intelligent consistent approach for replication and placement of IoT based on fog computing," *Egyptian Informatics Journal*, vol. 24, no. 2, pp. 327-339, 2023, doi: 10.1016/j.eij.2023.05.003.
29. M. A. A. Mousa, A. T. Elgohr, and H. Khater, "Path Planning for a 6 DoF Robotic Arm Based on Whale Optimization Algorithm and Genetic Algorithm," *Journal of Engineering Research*, vol. 7, no. 5, pp. 160-168, 2023, doi: 10.21608/erjeng.2023.237586.1256.
30. M. Alhamdany and H. Khater, "Proposed Approach for Automatic Underwater Object Classification," *ICIC Express Letters*, vol. 12, pp. 1205-1212, 2018.
31. H. Khater, S. Mesbah, and A. Anwar, "Enhanced navigation system for AUV using mobile application," *International Journal of Engineering Inventions*, vol. 5, no. 1, pp. 14-19, 2015.
32. M. A. A. Mousa, A. T. Elgohr, and H. A. Khater, "Trajectory Optimization for a 6 DOF Robotic Arm Based on Reachability Time," *Annals of Emerging Technologies in Computing (AETiC)*, vol. 8, pp. 22-35, 2024.

33. H. G. Mohamed, H. A. Khater, and K. H. Moussa, "An Intelligent Combined Visual Navigation Brain Model/GPS/MEMS–INS/ADSFCF Method to Develop Vehicle Independent Guidance Solutions," *Micromachines*, vol. 12, p. 718, 2021, doi: 10.3390/mi12060718.
34. W. Abdelmoez, H. Khater, and N. El-shoafy, "Comparing maintainability evolution of object-oriented and aspect-oriented software product lines," 2012 8th International Conference on Informatics and Systems (INFOS), Giza, Egypt, 2012, pp. SE-53-SE-60.
35. L. Alzubaidi et al., "Review of deep learning: concepts, CNN architectures, challenges, applications, future directions," *Journal of Big Data*, 2021.
36. J. Schmidhuber, "Deep Learning in Neural Networks: An Overview," *Neural Networks*, vol. 61, pp. 85-117, 2015.
37. L. Shen et al., "On Efficient Training of Large-Scale Deep Learning Models: A Literature Review," arXiv, 2023.
38. A. Kirsch, "Advancing Deep Active Learning & Data Subset Selection: Unifying Principles with Information-Theory Intuitions," arXiv, 2024.
39. M. Jogin et al., "Feature Extraction using Convolution Neural Networks (CNN) and Deep Learning," IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology, 2018.
40. L. Alzubaidi et al., "Review of deep learning: concepts, CNN architectures, challenges, applications, future directions," *Journal of Big Data*, 2021.
41. H. Gholamalinezhad and H. Khosravi, "Pooling Methods in Deep Neural Networks, a Review," arXiv, 2020.
42. M. Saeedan and M. Saeedan, "Detail-Preserving Pooling in Deep Networks," CVF Open Access, 2018.
43. S. H. Shabbeer Basha, S. R. Dubey, V. Pulabaigari, and S. Mukherjee, "Impact of Fully Connected Layers on Performance of Convolutional Neural Networks for Image Classification," Neurocomputing Journal, 2019.
44. K. Simonyan and A. Zisserman, "Very deep convolutional networks for large-scale image recognition," in 3rd Int. Conf. Learn. Represent. ICLR 2015 - Conf. Track Proc., 2015, pp. 1–14.
45. C. Zhang, E. Nateghinia, L. Miranda-Moreno, and L. Sun, "Pavement distress detection using convolutional neural network (CNN): A case study in Montreal, Canada," International Journal of Transportation Science and Technology, vol. 7, 2021, doi: 10.1016/j.ijtst.2021.04.008.
46. J. Brownlee, "Introduction to Regularization to Reduce Overfitting and Improve Generalization Error," Machine Learning Mastery, Jan. 10, 2020. [Online].

Available: https://machinelearningmastery.com/introduction-to-regularization-to-reduce-overfitting-and-improve-generalization-error/.

47. J. Brownlee, "How to Choose an Activation Function for Deep Learning," Machine Learning Mastery, Jan. 10, 2020. [Online]. Available: https://machinelearningmastery.com/choose-an-activation-function-for-deep-learning/.
48. O. Russakovsky et al., "ImageNet Large Scale Visual Recognition Challenge," International Journal of Computer Vision, vol. 115, pp. 211–252, 2015. [Online]. Available: https://link.springer.com/article/10.1007/s11263-015-0816-y.
49. A. Krizhevsky, I. Sutskever, and G. E. Hinton, "ImageNet Classification with Deep Convolutional Neural Networks," Advances in Neural Information Processing Systems, vol. 25, 2012.