Transforming patient care journey with traditional and generative AI

Abstract

Artificial intelligence (AI) has disrupted every industry with its ability to analyze vast amounts of data to make complex decisions. Within the healthcare sector, which deals with enormous volumes of structured and unstructured data, the possibilities of AI are immense.

However, AI is a broad term that covers various technologies—with Generative AI (GenAI) emerging as a promising entrant. GenAI, with its transformative capabilities in data synthesis, scenario exploration, and adaptive problem-solving, holds the key to reshaping healthcare.

Nonetheless, GenAI is still nascent and confronts several challenges that warrant attention.

To take advantage of this AI-fication of healthcare and prevent misapplication of functionalities, enterprises need to be clear on the distinction between GenAI and traditional AI technologies. This paper explains AI's diverse applications throughout the patient care journey while carefully distinguishing between GenAI and other AI technologies.

Introduction

The healthcare industry is constantly evolving. This rapid digitalization of an industry that has traditionally been averse to technology poses new challenges for all stakeholders. At the same time, embracing technological advancements welcomes elevated patient care, enhanced productivity, reduced administrative burden, expedited medical research, improved costs, and more.

How can healthcare enterprises future-proof their operations, mitigate the challenges, and take the leap? Artificial intelligence might be the answer they're looking for!

By harnessing the power of machine learning, robust datasets, problem-solving, and decision-making capabilities, artificial intelligence holds the potential to revolutionize healthcare.

Machine learning (ML), a subset of AI, utilizes algorithms to learn from data and make predictions. Deep learning (DL), a subset of machine learning, is rooted in neural networks that mimic the human brain's neurons and require extensive datasets for training. Natural Language Processing (NLP), another branch of AI, interprets, manipulates, and comprehends human language using machine learning and computational linguistics.

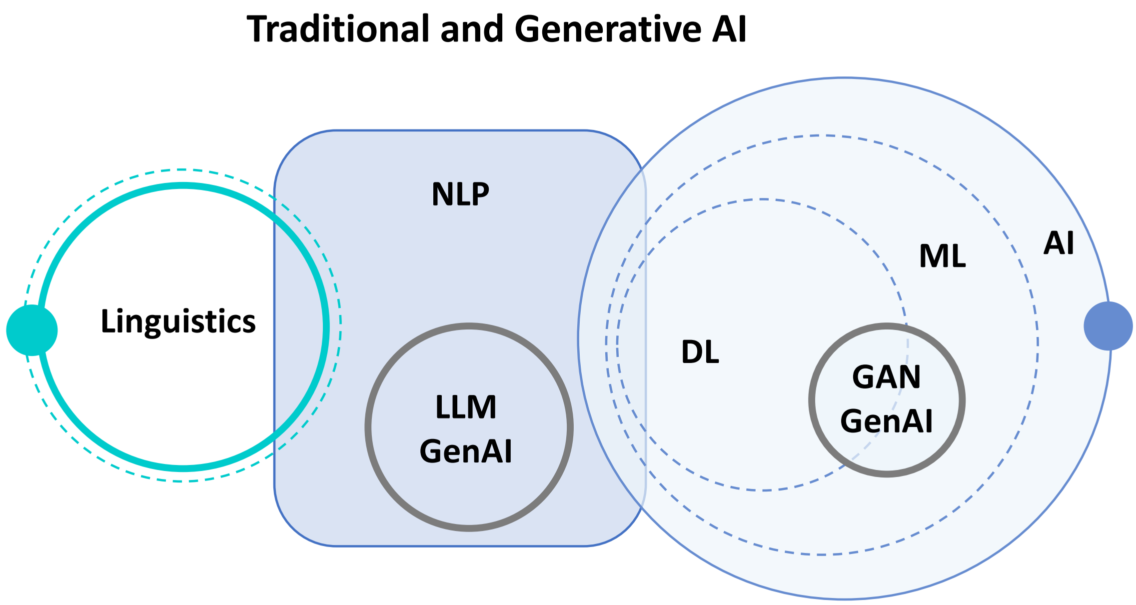


Exhibit 1 - Illustrating Traditional and Generative AI Models

- **Large language models (LLM):** are specific models used in NLP that utilize deep learning and massive datasets to excel in language-related tasks such as generating and predicting new content. LLM forms the basis of GPT and chatbots, which take unrestricted, complex, and vague text as input and generate authentic and precise output.

- **Generative adversarial network (GAN):** can generate new, synthetic data that follows the distribution on which it is trained. It comprises two neural networks, a Generator and a Discriminator, which compete using deep learning techniques to generate new samples by capturing and replicating variations in training data. The generator's function is to create fake data from random noise following uniform distribution, and that of the discriminator is to identify that data as real or fake as it's trained on real data.

When the discriminator can determine the generator's data as fake, the model training is complete, and new synthetic data resembling the original data is ready. The value function for GAN, explained by Goodfellow in 2014, is a minimax game between the generator and discriminator generated based on cross-entropy. The goal is to train the discriminator by maximizing its function, which implies that the discriminator gets awarded for classifying the real images as real and fake images as fake and trains the generator by minimizing its function, which means that it gets penalized when the discriminator classifies the image generated by it as fake.

$$\min_G \max_D V(D,G) = \mathbb{E}_{\boldsymbol{x}\sim p_{\text{data}}(\boldsymbol{x})}[\log D(\boldsymbol{x})] + \mathbb{E}_{\boldsymbol{z}\sim p_{\boldsymbol{z}}(\boldsymbol{z})}[\log(1 - D(G(\boldsymbol{z})))].$$

.........[1]

The issues with GAN are vanishing gradient, mode collapse, and non-convergence[2]. To overcome these challenges, GAN models are re-engineered with better design and optimization techniques. They are conditional GAN (cGAN), laplacian parameter GAN (LAPGAN), deep convolutional GAN (DCGAN), adversarial autoencoder (AE), generative recurrent adversarial network (GRAN), information maximizing GAN (InfoGAN), bidirectional GAN (BiGAN), super resolution GAN (SRGAN), progressive growing GAN (PGGAN), Pix2pix, etc.

Large Language Models (LLM) and Generative Adversarial Networks (GAN) can generate new data instances that resemble training data. Hence, LLMs and GANs are categorized as Generative AI models.

Traditional AI vs Generative AI: Understanding the differences and capabilities

Models that do not generate new content using AI are termed traditional AI, while models capable of generating newer content are referred to as Generative AI.

Traditional AI is designed to follow predefined rules and patterns. These models are trained on large, labeled datasets and then used to predict future instances. It is a mature technology that efficiently handles tasks such as automation, generating insights, predictive analytics, intelligent alerting, etc.

Generative AI, on the other hand, is an emerging technology that aims to create new data or content, such as text, images, video, etc. The generated data/content closely resembles human-created data by capturing underlying patterns and relationships within the data based on training. These models are creative and can handle uncertainty as well as missing information. Thus, traditional AI efficiently performs specific tasks, while Generative AI exhibits human-like creativity and adaptability.

Let's review scenarios in the patient care field where AI has made an impact.

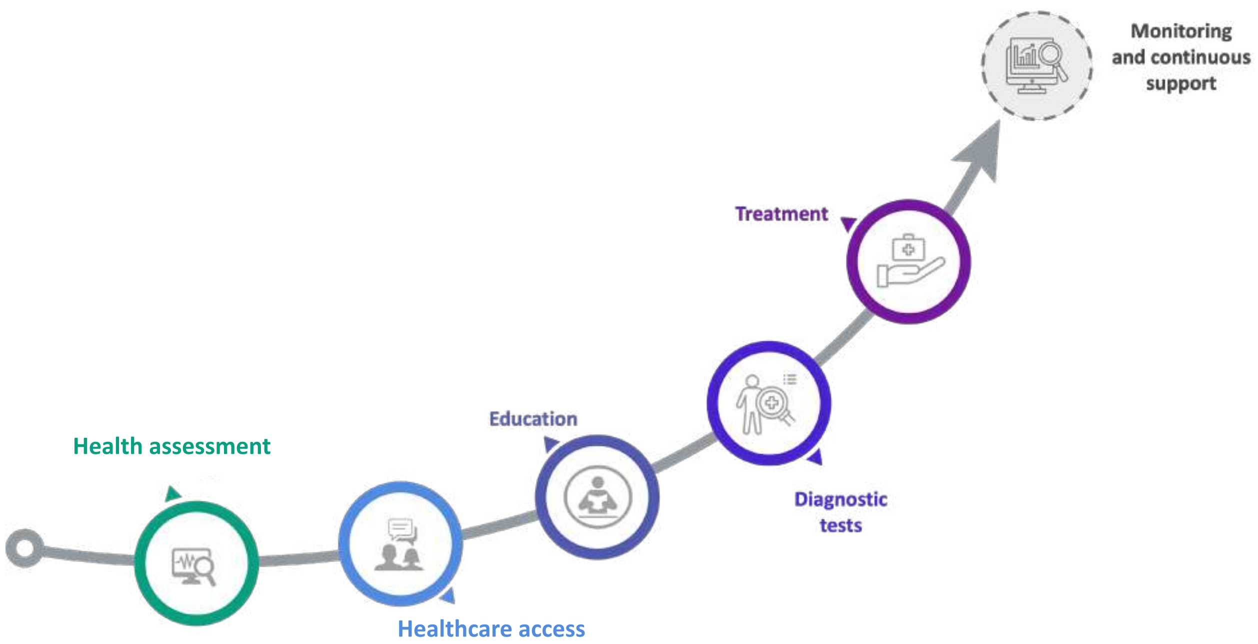


Exhibit 2- Patient Journey Stages

A patient care journey commences either with symptoms or with proactive health monitoring. It incorporates selecting a physician, scheduling an appointment, becoming aware of illness, undergoing diagnostic tests, receiving treatment, adhering to a healthy lifestyle, and ongoing support. The patient engagement solution market is projected to reach $41.8 bn by 2028, with a CAGR of 13.2% from 2023 to 2028, as per research.[3]

Providing a comfortable experience to patients by knowing their preferences and offering personalized treatments is vital in today's value-based healthcare world. The emergence of AI has reshaped the healthcare system. It can touch upon every aspect of the patient care journey and improve the experience of all the stakeholders involved.

We will now review multiple scenarios where AI can reimagine care delivery and outcomes.

Health assessment

Detecting diseases at the initial phase can be immensely beneficial, as it prevents disease progression, mitigates the risk of complications and potentially irreversible, life-threatening conditions in some instances, and, most importantly, improves treatment outcomes, and ultimately quality of life.

Leveraging machine learning techniques such as Support Vector Machines (SVM), decision trees, regression analysis, clustering algorithms, random forests, and Principal Component Analysis (PCA), advanced clinical decision support solutions can augment healthcare professionals to recommend specific diagnostic tests tailored to individual patient based on the demographics, medical records, family history, current treatments, lifestyle factors, and more. This personalized approach minimizes the need for multiple tests by providing individualized test recommendations, thereby optimizing healthcare resources, improve healthcare outcomes, and reducing costs.

Healthcare access

Selecting the appropriate healthcare facility is crucial to ensuring the best possible care with reduced cost burden and easy accessibility. Machine learning algorithms have the capability to aid patients in making informed choices by analyzing parameters such as location, medical specialties, quality ratings and reviews, insurance acceptance, cost, availability, patient needs and preferences.

The next important step is scheduling appointments based on patient preference, medical urgency, physician schedule, and availability of facility resources.

Effective appointment scheduling can help optimize medical resource utilization, including staff and facilities, while simultaneously reducing patient wait times and healthcare costs. This optimization not only enhances fairness and patient safety but also significantly improves overall patient satisfaction. Currently, machine learning algorithms, coupled with optimization techniques, are the kingpins of decision-making processes related to appointment scheduling. These algorithms predict the likelihood of patients arriving on time, allowing optimization algorithms to minimize patient discrimination, reduce waiting times, and maximize provider efficiency. Interestingly, while several optimization algorithms, such as particle swarm optimization (PSO), ant colony optimization (ACO), and whale optimization algorithm (WOA), are employed in appointment scheduling, PSO has emerged as the most efficient method in practice.

Moreover, machine learning models can assess the probability of high-risk patients missing or canceling appointments due to traffic or adverse weather conditions. It has been observed that automated reminders and personalized communications from medical staff have significantly reduced appointment cancellations, resulting in cost savings for healthcare providers and bolstering patient trust and satisfaction.

Additionally, integrating chatbots with scheduling software offers patients and providers a seamless and user-friendly booking experience, streamlining the entire process and enhancing overall efficiency.

- **Patient history summarization, real-time transcription, and recommendations**

LLMs can assist physicians by creating a comprehensive patient history summary based on their previous reports in the context of an episode. They also support real-time transcription of dialogues between patients and physicians (in multiple languages) while extracting critical information such as symptoms, medications, medical history, etc.

Leveraging patient history and real-time transcription, LLMs is capable to recommend diagnostics tests and treatments if trained with medical data from textbooks, journals, clinical notes, and patient records. As these models can integrate various tools such as Word, PDF, PPT, voice, and others, they can create relevant documentation and recommendations, assisting physicians, reducing their burden, and allowing them to focus on patient care.

Milestone	Tasks	ML	DL	GenAI
Health assessment	Recommending diagnostic tests	✓		
Healthcare access	Appointment scheduling	✓		
	Patient history summarization			✓
	Recommendations			✓
Patient education	Disease/ procedure/treatment awareness			✓
Early & accurate disease diagnosis	Imaging protocol recommendations	✓		
	Image resolution enhancement		✓	✓
	Image augmentation		✓	✓
	Image segmentation & classification		✓	✓
	Image registration & translation		✓	✓
	Report generation		✓	✓
Treatment	Treatment/procedure recommendation	✓		
Monitoring and continuous support	Tracking treatment, reports and alerting		✓	✓

Exhibit 3 - Role of AI in Patient Journey

Patient education

Patient awareness surrounding illness, symptoms, and procedures is crucial for self-help, treatment choices, engagement, and effective treatment. Educating patients before major procedures ensures they have completed necessary tasks, promoting comfort and preparedness for the patient and the caregiver.

In the case of chronic diseases like diabetes, asthma, Alzheimer's, and arthritis, a patient's knowledge about their condition, the importance of lifestyle choices, and treatment adherence are pivotal, as most therapy occurs at home. AI health chatbots, trained in medical literature, offer an interactive solution.
They converse in the patient's preferred language and generate self-help articles for easy reference. This ability to create patient-specific content in multiple languages along with being contextual and empathetic enhances understanding and acceptance.

Imaging protocol recommendations

In diagnostic radiology, imaging protocols are critical in obtaining high-quality images at a reasonable cost. Technicians meticulously set specific parameters, including the field of view (DFOV), breath-hold duration, oral and intravenous contrast administration, contrast delay, and radiation dose, while ensuring optimal patient positioning for effective scans.

The selection of imaging protocols is contingent upon various factors such as the type of modality, the specific organ being imaged, the imaging technique employed, the patient's clinical condition, and demographic characteristics. However, technicians often need help with protocol variability and consistency, which can result in disparities in diagnosis.

Leveraging machine learning models trained with standardized protocols to address these challenges proves highly effective. Implementing ML models to recommend optimal imaging protocols significantly reduces the burden on radiologists, and a consistent imaging experience is achieved across different patients and imaging scenarios.

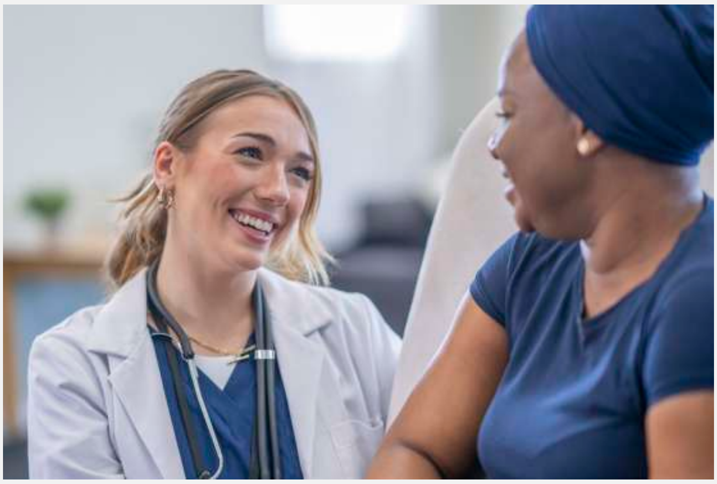
Disease diagnosis

Diagnostic medical imaging is widely utilized in detecting diseases such as glaucoma, cancer, cardiovascular disorders, neurological conditions, and more. However, diagnosis based solely on medical images is ineffective for early disease detection and accuracy. To combat these challenges, AI technologies, including deep learning techniques like CNN, RNN, and FCN, can be employed to automate tasks such as image registration, segmentation, annotation, and fiducial detection.

Persistent challenges in medical imaging include low image resolution, complex image structures, class imbalances, limited annotated datasets, sparse annotations, and intensity inhomogeneity. Generative AI, particularly GANs, offers solutions to address some of these challenges.

Here's how Generative AI model (GAN) can improve disease diagnosis:

- Low-resolution images hinder deep learning model performance, affecting image segmentation and automated diagnosis. SRGAN and Enhanced SRGAN (ESRGAN) effectively upscale images up to four times with minimal information distortion.
- The imbalanced dataset problem arises from disproportionate instances of one class over others, resulting in biased predictions and poor performance. Image augmentation techniques such as geometric transformation and color distortion help mitigate this issue but can lack diversity. To tackle this, DCGAN and cGAN can generate synthetic images resembling the original ones, aiding in overcoming class imbalance.
- Image segmentation and classification are crucial for identifying organ or lesion boundaries and measuring tissue volume, aiding in disease detection and treatment planning. Various GAN models, such as classic vanilla GAN, Cycle GAN, cGAN, and others, improve the accuracy of medical image segmentation under various conditions such as brain tumors, cardiac anomalies, lung tumors, retina diseases, skin lesions, liver tumors, and orthopedic diseases[4], by effectively capturing underlying data relationships.
- GANs find applications in image registration and translation. Image registration aligns images from different modalities of the same patient, aiding in patient position verification, treatment planning, and assessment during radiation therapy. MedGAN[5], on the other hand, can translate medical images across modalities, reducing delays, healthcare costs, and radiation exposure.



- **Diagnostic report generation**

Generative AI LLMs can assist radiologists in report generation based on automated diagnosis and disease progression detection. This can enhance diagnosis accuracy and reduce the burden on radiologists.

Treatment recommendations and precision medicine

ML models can assist physicians in recommending treatment or identifying a patient's suitability for specific procedures based on their patient history, current condition, medical reports, and demographics.

Prevention and treatment strategies based on an individual's genetic profile and lifestyle can help in early and precise diagnosis and effective cure methodology. Machine learning and deep learning models are game changers in this field, as they can easily identify underlying patterns in large datasets with multiple features.

Patient monitoring and continuous support

Monitoring patient health and providing continuous support improves health outcomes, reduces healthcare costs, and avoids complications. AI models can analyze various medical data obtained from multiple medical devices to identify clinically significant parameters, measure clinical significance and risks, and share the analysis with physicians for the next steps. This analysis can include the patient's condition, medical reports, and demographics.

Challenges and opportunities in GenAI

Despite rapid advances in GenAI models, they face specific technical and ethical challenges, which provide opportunities for improvement [6]. Some of these challenges are outlined below:

- **Hallucination:** LLMs are known to hallucinate, which refers to generating text that is factually incorrect, contradictory, nonsensical, erroneous, or detached from reality. Poor data quality, biases while training, overfitting, not being trained for specific objectives, and unclear prompts are a few causes of such behavior. This is a significant concern, especially in healthcare.

- **Lack of transparency:** Transparency is the ability to investigate an AI model's inner workings. Understanding the path to the solution provided by the model is fundamental. Hence, a generated output or decision must be explained and scrutinized to maintain credibility.

- **Biases:** If the datasets on which LLMs are trained are biased, then the generated data from this model will also be biased. This can result in social inequalities and discrimination while generating healthcare-related content or decisions.
- **Data privacy:** Protecting sensitive health data per government regulations is indispensable for maintaining patients' trust and an enterprise's reputation. Being computationally heavy, LLMs cannot be accommodated on proprietary hardware. As a result, institutions must rely on third-party servers, which increases the chances of data theft or breaches.
- **High cost and response time:** LLMs have high response times and high financial costs due to the need for many computations and associated complexity. This is a crucial factor for healthcare providers as it increases the overall cost.

Conclusion

AI has the potential to transform healthcare due to its ability to reduce human errors, assist medical professionals by providing recommendations, reduce administrative burden, and provide continuous support to patients. It has applications in the patient care journey, from disease detection to personalized treatment.

Healthcare providers leveraging the benefits of AI must consider the following factors while implementing such models in practical use:

- Carry out the cost-benefit analysis to ensure feasibility and impact.
- Establish effective mechanisms to measure the impact of AI/ML performance to justify whether it's a practice expense or an investment.
- Evaluate the quality of AI-generated output to reduce hallucination.
- Train the implemented model on large datasets with minimum bias.
- Conduct the training of AI models at regular intervals to reduce bias and generate unbiased output.
- Obtain patient consent before using their data for training purposes.
- Take sufficient measures to ensure data privacy and compliance with all regulations.

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