AI-Driven Early Diagnosis and Digital Therapeutics for Neurological Disorders --Leveraging AI for Early Detection and Management

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Organization

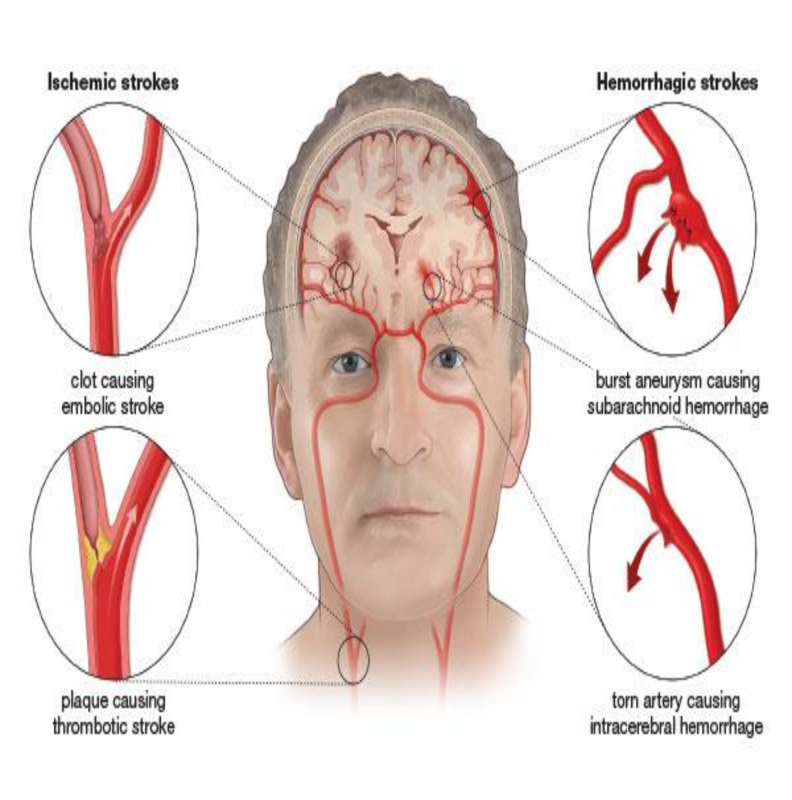
- What are MS and Stroke
- AI driven methods and how they may be used
- Foundational Basics of AI
- Generative AI; Recurrent NN; Transfer Learning; Diffusion Models
- AR/VR and a proof of Concept

•**Neurological Disorders:**
Leading cause of disability and death worldwide
Importance of early detection and efficient management

In 2021, it was reported that 43% of the global population—approximately 3.4 billion individuals—was affected by neurological conditions

Recent data shows a 39% rise in neurological disease-related deaths over the past three decades.

Managing neurological conditions such as **stroke** and **multiple sclerosis (MS)**.
Early and continuous rehabilitation is vital to regaining lost motor skills and cognitive function, with 60% of stroke survivors developing long-term disabilities.



Every 40 seconds, someone in the United States has a stroke[1].

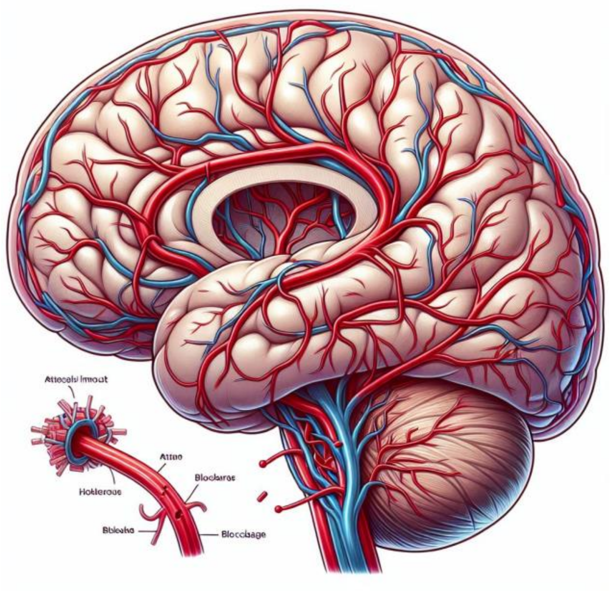
Every 3 minutes and 11 seconds, someone dies of a stroke in the United States[1].

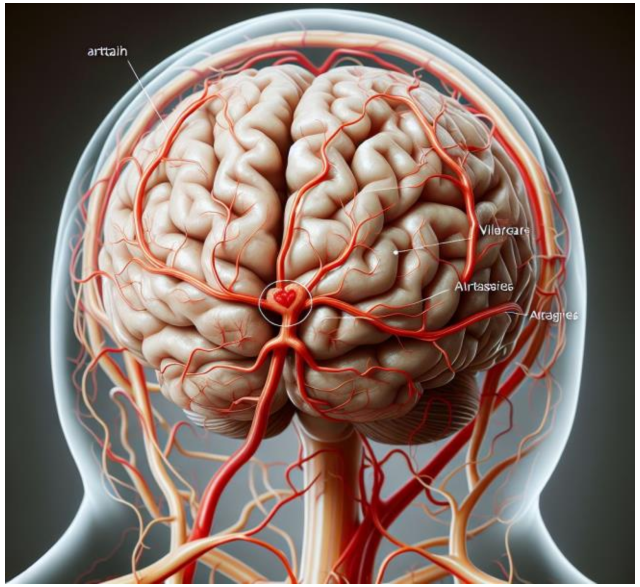
Stroke is the fifth leading cause of death in the United States[2].

About 795,000 people in the United States have a stroke each year[1].

Stroke-related costs in the United States were nearly $56.2 billion between 2019 and 2020[1].

MS -- Affects over 1.8 million people worldwide, more common in young adults and females[2]





What is a Stroke?

- A stroke, also known as a brain attack, occurs when blood flow to a part of the brain is interrupted or reduced, preventing brain tissue from getting oxygen and nutrients[1].
- Types:
  - **Ischemic Stroke:** Caused by a blockage in an artery (accounts for about 85% of strokes)[1].
  - **Hemorrhagic Stroke:** Caused by a blood vessel bursting in the brain[1].

What is Multiple sclerosis

- MS is a chronic autoimmune disease affecting the central nervous system (CNS), where the immune system attacks the myelin sheath covering nerve fibers[1].

- Symptoms and Causes of MS
  - Symptoms: Visual changes, numbness, tingling, muscle weakness, coordination issues, fatigue, and cognitive changes[13].
  - Causes: Exact cause unknown, but involves immune system malfunction, genetic factors, and environmental triggers[3].
  - Risk Factors: Age (20-40 years), gender (more common in women), family history, low vitamin D levels, smoking[3].

Diagnosis and Treatment

- Diagnosis: MRI, spinal tap, blood tests, and nerve conduction studies[14].
- Treatment: No cure, but treatments include corticosteroids, disease-modifying therapies, physical therapy, and lifestyle changes[14].

The Role of AI

AI-Driven Methods:

- Early diagnosis of neurological disorders
- Causal and interelationships
- Digital Therapeutics (DTx)
- Real-time data driven management of neurological disorders

The Role of AI

AI is set to play a transformative role in digital therapeutics by enhancing personalization, proactivity, and efficiency in healthcare.

1. **Personalization**: AI enables digital therapeutics to tailor treatments to individual patients. –
    1. personalized medication reminders, tailored exercise programs, and specific dietary recommendations[1].
2. **Predictive Analytics**: AI's ability to predict future health states based on current and historical data helps in early intervention and prevention.
3. **Enhanced Engagement**: Provide interactive and adaptive content. -- virtual coaching, gamified health activities, and real-time feedback.
4. **Automation and Efficiency**: AI automates routine tasks such as patient monitoring and data analysis, freeing up healthcare professionals to focus on more complex cases.
5. **Data-Driven Insights**: AI can analyze large datasets to uncover insights that might be missed by human analysis. These insights can inform treatment plans, identify at-risk populations, and improve overall healthcare strategies[4].

What is AI

Science and technology to simulate human intelligence by machines and computers

- Examples: Autonomous vehicles, crop analysis; drug discovery; medical diagnosis; Generative AI tools

Machine Learning; Deep Learning; Rule based

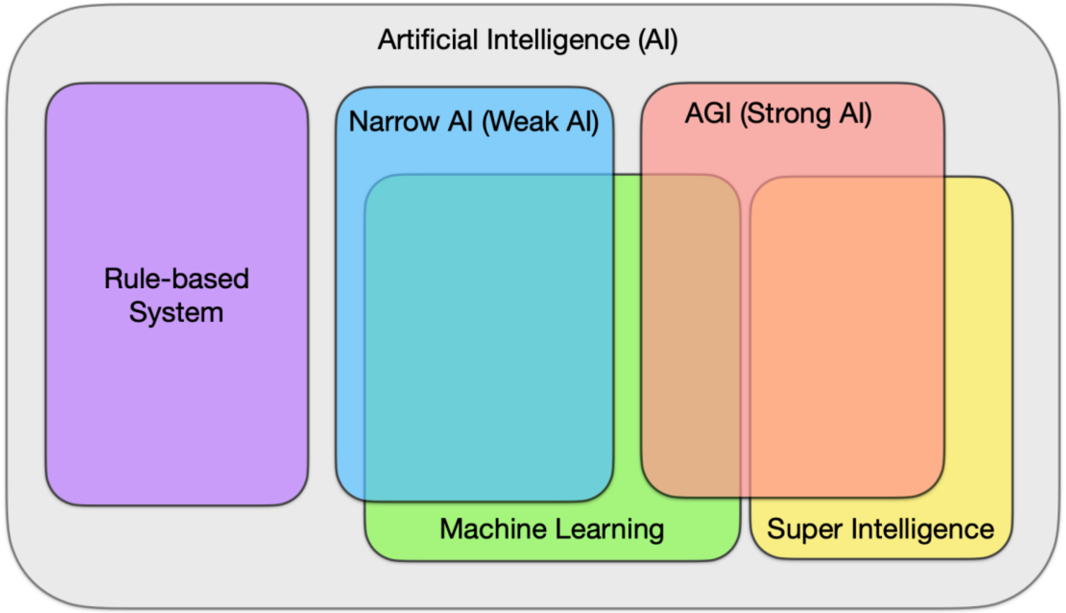
Based on the human decision-making processes that can learn and generalize

Narrow AI (ANI-Artificial Narrow Intelligence)

- Trained and focused on specific tasks– Apple's Siri, Amazon's Alexa, IB Watsonx™, Self-Driving Vehicles

Strong AI (AGI-Artificial General Intelligence or Artificial Super Intelligence)

- Aims for intelligence equivalent to humans—Self aware; consciousness ability to solve problems; plan for the future
- ASI- Surpass the human abilities and intelligence– at present mostly theoretical
- Examples: Superhuman and rogue computer assistant in 2001: A Space Odyssey

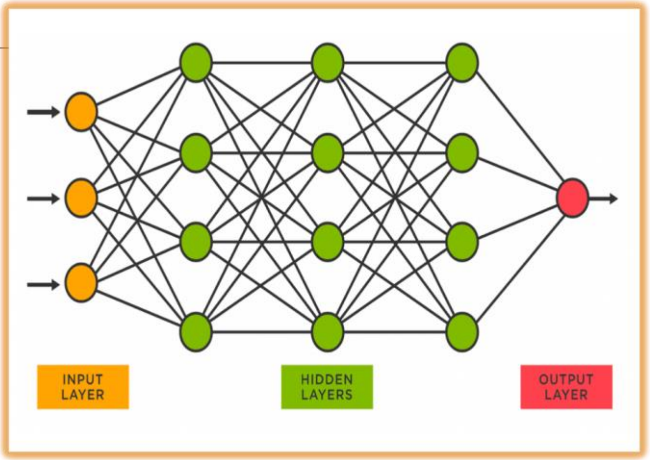


Generative AI

Deep learning that takes raw data (Wikipedia; works of Rembrandt, etc) and can generate statistically probable outputs

Encode a simplifies description of training data and generate new work that may be similar but not identical to the original data

How deep learning works



Multiple layers of interconnected nodes

Backpropagation- Error is backpropagated to adjust weights to learn the patterns

Massive set of neurons – require massive resources

High performance graphical processing units – calculations in multiple cores with large memory

Distributed cloud computing is good

Software requirements– typically JAX, PyTorch, TensorFlow

PyTorch

TensorFlow

Jax

History

1950

Alan Turing – *Computing Machinery and Intelligence.*

Can Machines Think?

Turing Test

1956

John McCarthy "artificial intelligence"

Newell, Shaw, Simon create the first running AI software program Logic Theoris

1967

Mark Rosenblatt – Mark 1 Perceptron, NN that learns

Minsky and Papert book Perceptrons - argument against NN

1980

BP becomes widely used

1997

IBMs Deep Blue beats world chess champion Garry Kasparov

2004

John McCarthy writes a paper "What is Artificial Intelligence" and defines AI

2011

IBM Watson beats champions Ken Jennnings and Brad Rutter at Jeopardy

2015

Baidu's Minwa supercomputer uses convolutional neural networks to identify and categorize images better than an average human

2016

DeepMind's AlphaGo program using deep neural network beats Lee Sodol, the world Go player (possible moves 14.5 trillion after four moves)

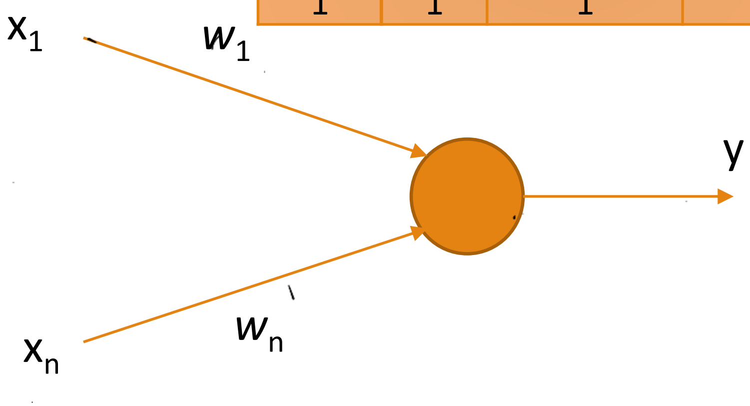
2023

Rise in Large Language Models, such as ChatGpt

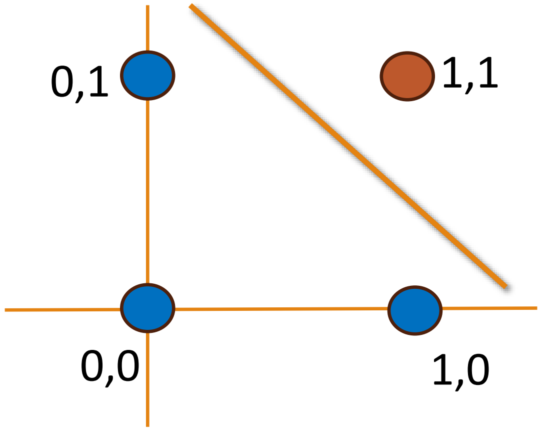
Background – Neuron --Perceptrons

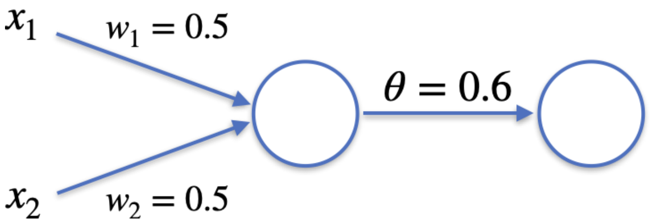
Implementation of AND XOR?

Input		And	XOR
X_1	X_2		
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0



$$y = f\left(\sum w_i x_i\right) = \begin{cases} 0, & \text{if } f < \theta \\ 1, & \text{if } f \geq \theta \end{cases}$$





$$y = f(x_1 * w_1 + x_2 * w_2)$$
$$y = f(0 \times 0.5 + 0 \times 0.5) = f(0) = 0$$
$$y = f(0 \times 0.5 + 1 \times 0.5) = f(0.5) = 0$$
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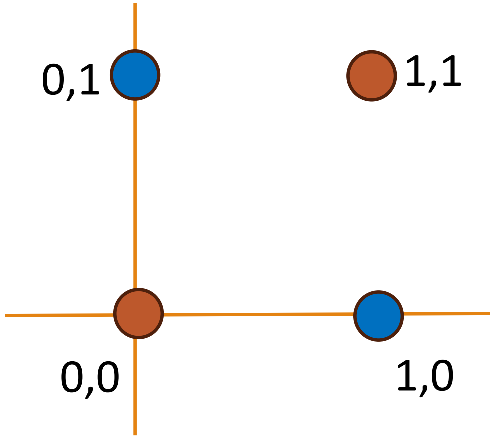
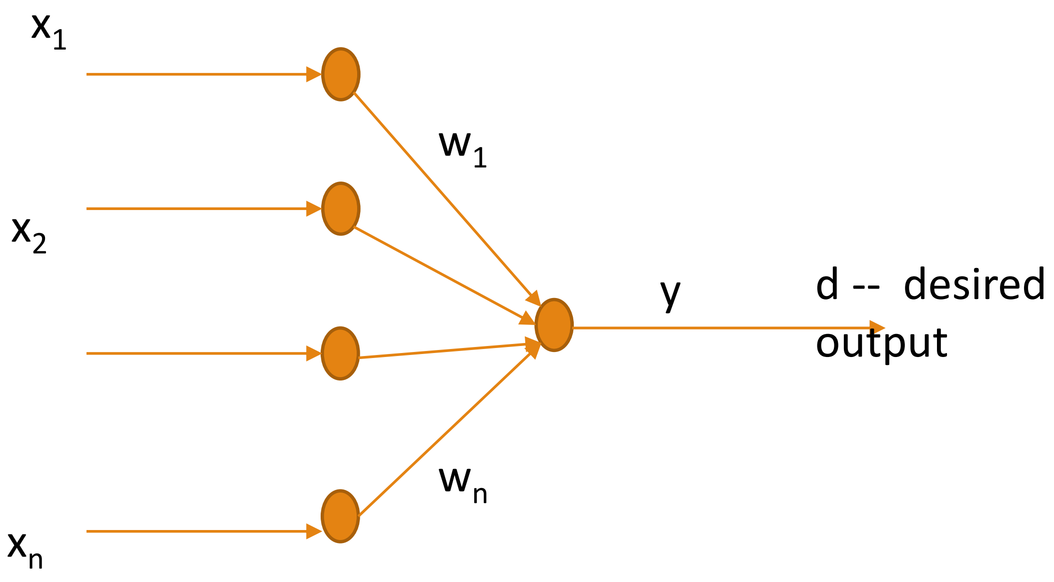
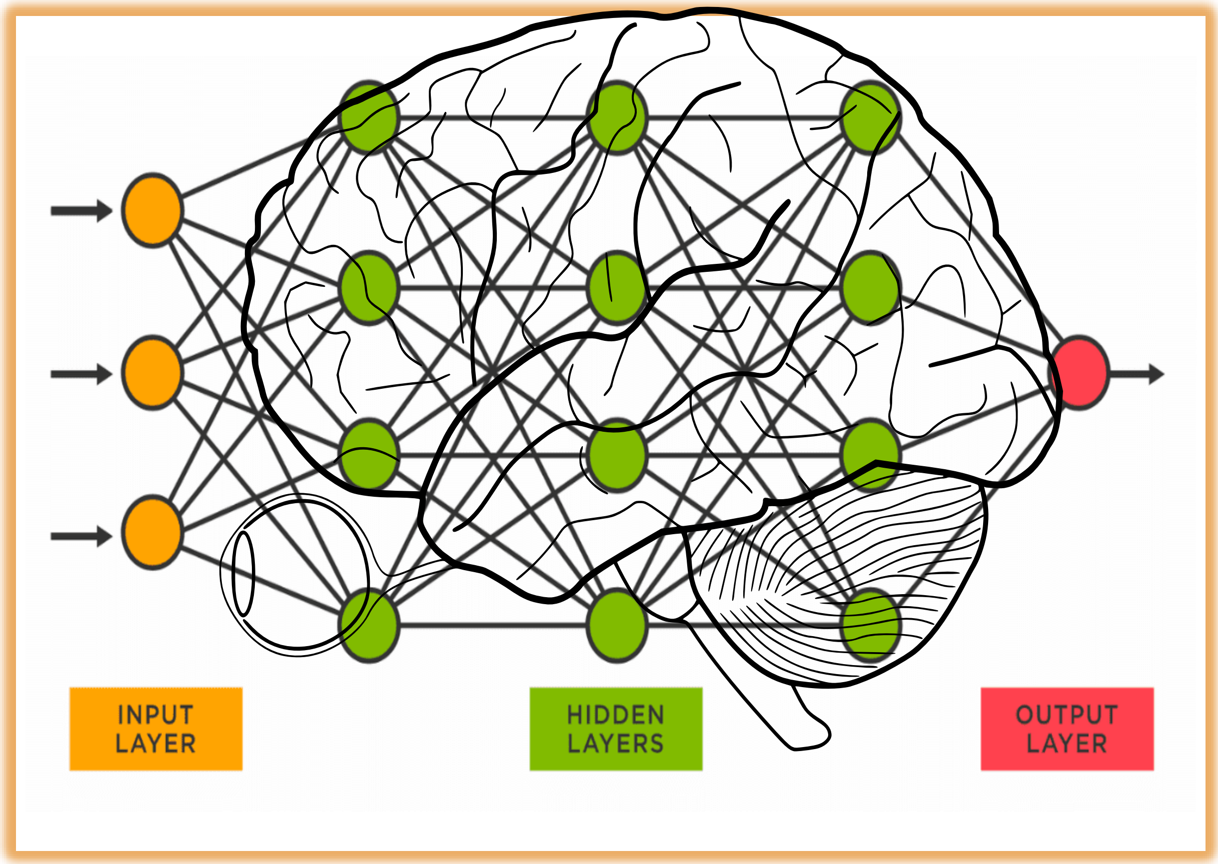


Perceptron



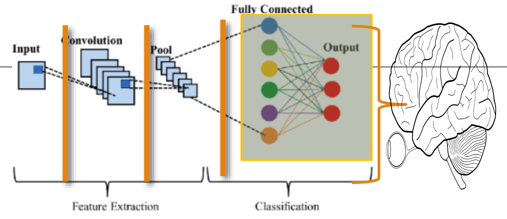
x_1
x_2
x_n
w_1
w_n
y
d -- desired output

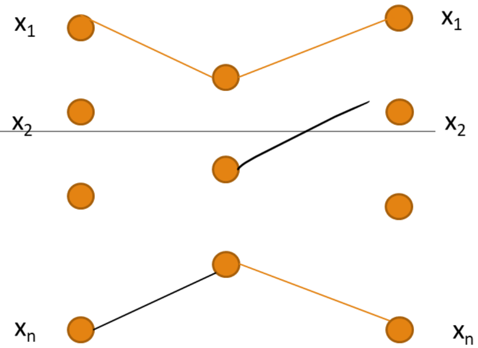


INPUT LAYER
HIDDEN LAYERS
OUTPUT LAYER

Types of deep learning -- 1

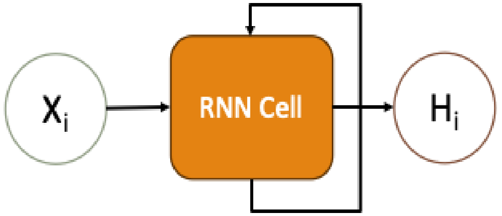
Convolutional neural networks (CNNs)

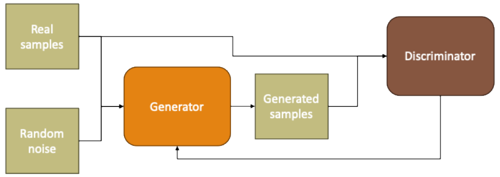




Recurrent Neural Networks (RNNs) – Uses a BPTT

Autoencoders and variational autoencoders





Generative Adversarial Networks

Convolutional Neural Networks

Used primarily in image processing and vision

At least three main types of layers: a convolutional layer, pooling layer and fully connected (FC) layer.

“convolution”—working and reworking the original input—detailed patterns can be discovered.

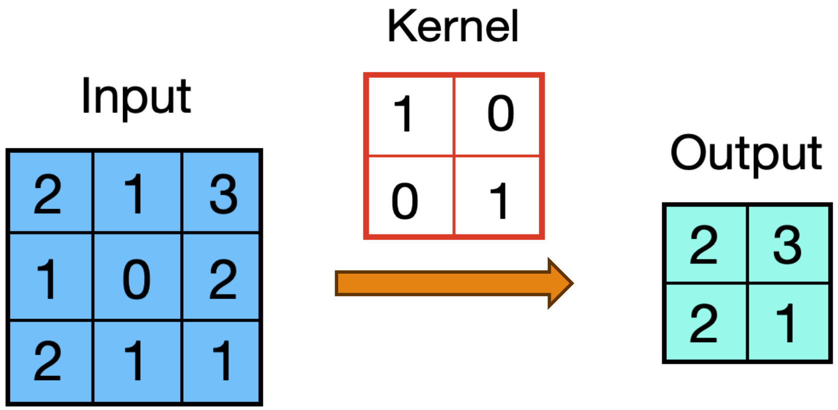
Earlier layers of a CNN detect simple features like colors and edges. As data moves through the layers, the network recognizes larger shapes and eventually identifies the object.

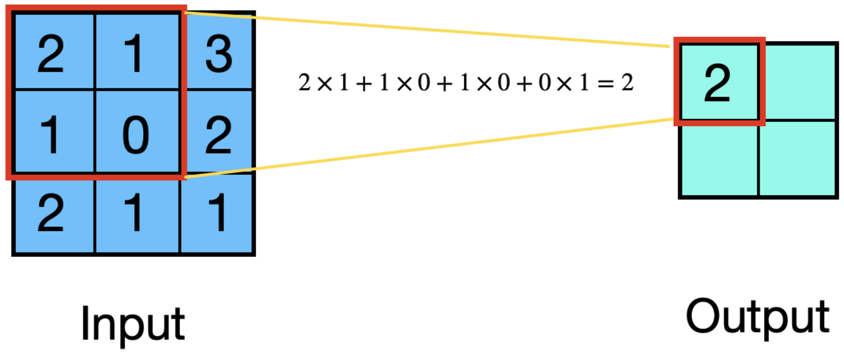
Convolutional Neural Networks

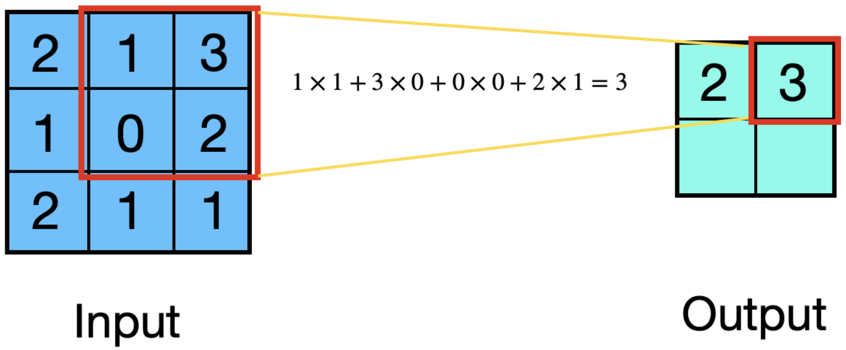
A simple example shows how CNN works:

Suppose we have a 3*3 matrix as input.

We apply a CNN layer with a 2*2 kernel, padding is 0, and stride length is 1







CNNs in Stroke and MS

Stroke

1. **Lesion Detection and Segmentation**: Used to analyze MRI and CT scans to detect and segment stroke lesions. --, which is crucial for planning treatment.

2. **Predicting Outcomes**: Can predict the outcomes of stroke treatments by analyzing imaging data and clinical parameters. -- potential recovery and planning personalized rehabilitation programs1.

3. **Automated Diagnosis**: Assist in the rapid and accurate diagnosis of stroke by differentiating between ischemic and hemorrhagic strokes. -- Essential for timely and appropriate treatment[3].

4. **Treatment Planning**: By analyzing imaging data, CNNs can help in planning interventions such as thrombolysis or thrombectomy, ensuring that patients receive the most effective treatment based on their specific condition2.

Multiple Sclerosis (MS)

1. **Lesion Detection and Classification**: CNNs are used to detect and classify MS lesions in MRI scans. They can differentiate between active and inactive lesions, which is important for monitoring disease progression and treatment response4.

2. **Disease Progression Prediction**: CNNs analyze longitudinal MRI data to predict the progression of MS. Helps in identifying patients at risk of rapid progression and adjusting treatment plans accordingly4.

3. **Patient Stratification**: CNNs can stratify MS patients into different categories based on disease severity and progression. This helps in tailoring treatment strategies to individual patient needs[4].

4. **Monitoring Treatment Efficacy**: By comparing MRI scans over time, CNNs can evaluate the efficacy of disease-modifying therapies (DMTs). This helps in optimizing treatment plans and improving patient outcomes[5].

Recurrent Neural Networks

Used in natural language and speech recognition applications as they use sequential or time-series data

“memory” as they take information from prior inputs to influence the current input and output

Uses Back Propagation through time

BPTT differs from the traditional approach in that BPTT sums errors at each time step,

How RNNs in Stroke and MS

Recurrent Neural Networks (RNNs) are highly effective in managing both stroke and multiple sclerosis (MS) due :

Stroke

1. **Predicting Stroke Onset**: RNNs can analyze time-series data from wearable devices and electronic health records to predict the likelihood of a stroke. By continuously monitoring vital signs and other health metrics, RNNs can identify patterns that precede a stroke, enabling early intervention[1].
2. **Rehabilitation and Recovery**: By analyzing data from physical therapy sessions, RNNs can adapt exercises to the patient's progress, ensuring that the rehabilitation process is both effective and tailored to individual needs[2].
3. **Speech and Language Therapy**: Stroke patients often suffer from aphasia, a condition that affects their ability to communicate. RNNs can assist in speech and language therapy by analyzing speech patterns and providing real-time feedback, helping patients improve their communication skills[3].
4. **Monitoring and Predicting Outcomes**: RNNs can track a patient's recovery progress and predict long-term outcomes based on their rehabilitation data. This helps healthcare providers adjust treatment plans as needed to optimize recovery[4].

Multiple Sclerosis (MS)

1. **Disease Progression Prediction**: RNNs can analyze longitudinal patient data, including MRI scans and clinical records, to predict the progression of MS.
2. **Severity Assessment**: RNNs are used to assess the severity of MS by integrating multimodal data such as neuroimaging, electronic health records (EHR), and clinical notes.
3. **Monitoring Treatment Response**: RNNs can track patient responses to various treatments over time, providing insights into the effectiveness of different therapies.
4. **Early Detection of Relapses**: By monitoring ongoing patient data, RNNs can detect early signs of MS relapses. This allows for timely interventions, potentially reducing the severity and impact of relapses[7].

GANs

Generative Adversarial Networks (GANs) are a class of machine learning frameworks designed by Ian Goodfellow and his colleagues in 2014.

Two neural networks, the generator and the discriminator, which are trained simultaneously through a process of competition.

How GANs Work

1. **Generator**: The generator creates synthetic data (e.g., images, text) that mimics real data. It starts with random noise and learns to produce data that becomes increasingly realistic over time.

2. **Discriminator**: The discriminator evaluates the data produced by the generator and distinguishes between real data (from the training set) and fake data (from the generator). It provides feedback to the generator on how to improve.

3. **Adversarial Training**: The generator and discriminator are trained together in a zero-sum game. The generator aims to produce data that can fool the discriminator, while the discriminator aims to correctly identify real versus fake data. This adversarial process continues until the generator produces data that is indistinguishable from real data.

Key Components

- **Loss Functions**: Both networks use loss functions to measure their performance. The generator's loss function measures how well it fools the discriminator, while the discriminator's loss function measures how well it distinguishes real from fake data.

- **Training Process**: The training involves alternating between updating the generator and the discriminator. This iterative process helps both networks improve over time.

GANs in Stroke and MS

Stroke

1. **Data Augmentation for Rehabilitation**: GANs can generate synthetic kinematic data that closely mimics the movement patterns of stroke survivors. This augmented data can be used to train machine learning models, improving the accuracy of activity recognition systems used in stroke rehabilitation[1]. This helps clinicians monitor patient progress more accurately and tailor interventions more effectively.

2. **Lesion Segmentation**: GANs are used to enhance the segmentation of stroke lesions in medical imaging. By generating realistic synthetic images, GANs help improve the training of segmentation models, leading to more accurate identification of stroke-affected areas[2].

3. **Simulating Post-Stroke Movements**: GANs can simulate realistic post-stroke reaching movements, capturing the complex temporal dynamics and common movement patterns. This helps in developing better rehabilitation strategies and tools[3].

Multiple Sclerosis (MS)

1. **Lesion-Specific Image Synthesis**: GANs can synthesize high-contrast MRI images from lower-contrast inputs, enhancing the visibility of MS lesions. This helps in better detection and monitoring of lesions, improving the accuracy of diagnosis and treatment planning[4].

2. **Data Augmentation for Diagnostic Models**: GANs can generate synthetic MRI data to augment training datasets, addressing the issue of data scarcity in MS research. This improves the performance of diagnostic models by providing more diverse and representative training examples[5].

3. **Predicting Disease Progression**: GANs can be used to predict the progression of MS by generating synthetic data that reflects various stages of the disease. This helps in understanding how the disease evolves and in developing personalized treatment plans[6].

Types of deep learning – Diffusion models

1. Forward Diffusion Process

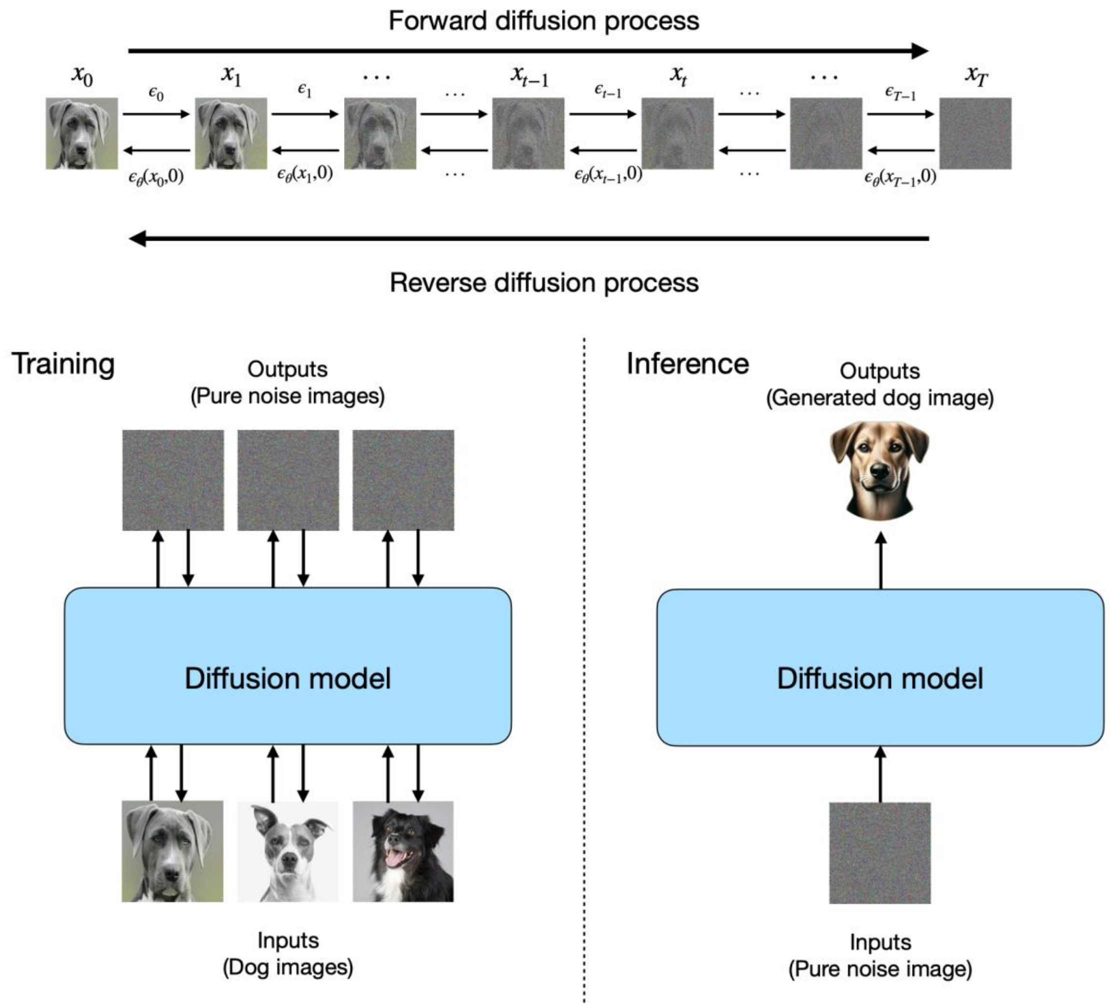
The model starts with a clean image (original image) and gradually adds noise to it over a series of time steps.

2. Reverse Diffusion Process

The goal of the model is to learn the reverse process: given a noisy image at any time step, the model learns to predict the slightly less noisy version of the image from the previous time step

3. Image Generation

During inference, starting with pure noise, the trained model gradually removes the noise step by step, eventually reconstructing an image that resembles the learned data distribution.



Diffusion Models in Stroke and MS

Diffusion models of learning, particularly those involving diffusion-weighted imaging (DWI) and diffusion tensor imaging (DTI), are proving to be highly valuable in the management of both stroke and multiple sclerosis (MS). Here's how they are being utilized:

Stroke

1. **Early Detection and Diagnosis**: detect acute ischemic strokes by identifying abnormalities in water diffusion within brain tissues.

2. **Lesion Segmentation**: assist in segmenting stroke lesions from MRI scans. -- assessing the extent of brain damage and planning appropriate interventions[2].

3. **Predicting Outcomes**: Can predict the likely outcomes of stroke treatments. This includes forecasting the recovery of brain tissue and the potential for functional recovery,

Multiple Sclerosis (MS)

1. **Lesion Detection and Classification**: Detect and classify MS lesions (active and inactive lesions) in the brain and spinal cord which is important for monitoring disease activity and progression[3][4].

2. **Assessing White Matter Integrity**: DTI, a type of diffusion imaging, is particularly useful in assessing the integrity of white matter tracts in MS patients --understanding the extent of neurodegeneration and its impact on cognitive and motor functions[5].

3. **Monitoring Disease Progression**: Diffusion models can track changes in brain structure over time, providing insights into the progression of MS. This information is valuable for adjusting treatment strategies and improving patient outcomes[4].

4. **Evaluating Treatment Efficacy**: By comparing diffusion imaging data before and after treatment, these models can evaluate the efficacy of therapeutic interventions.

Transfer Learning

How Transfer Learning Works

1. **Pre-training**: A model is first trained on a large dataset for a related task. For example, a neural network might be trained on a massive image dataset like ImageNet to recognize general objects.
2. **Transfer**: The pre-trained model is then adapted to a new, but related task. This involves fine-tuning the model on a smaller, task-specific dataset. For instance, the pre-trained image recognition model could be fine-tuned to identify specific medical conditions in MRI scans.

Benefits of Transfer Learning

1. **Reduced Training Time**: Since the model has already learned general features from the pre-training phase, it requires less time and computational resources to adapt to the new task.
2. **Improved Performance**: Transfer learning often leads to better performance, especially when the new task has limited data. The pre-trained model brings in valuable knowledge that helps in achieving higher accuracy.
3. **Efficiency with Limited Data**: It is particularly useful in scenarios where collecting a large amount of labeled data is challenging. The pre-trained model can effectively leverage the smaller dataset for the new task.

Transfer Learning Stroke and MS

Stroke Rehabilitation

1. **Motor Imagery (MI) Brain-Computer Interface (BCI) Systems**:
    1. Transfer learning can be used to adapt models trained on healthy individuals to work with stroke patients. This involves fine-tuning pre-trained models to recognize and interpret the specific brain signals of stroke patients during motor imagery tasks[1].
    2. For example, a study used a combination of EEGNet and fine-tuning techniques to improve the performance of MI-based BCI systems for stroke rehabilitation. This approach significantly reduced training time and improved classification accuracy[1].
2. **Session-to-Session Transfer**:
    1. Transfer learning strategies can be employed to enhance the consistency of BCI performance across different sessions for the same patient. This helps in maintaining the effectiveness of rehabilitation over time[2].

Multiple Sclerosis (MS)

1. **Cognitive Training**:
    1. Transfer learning can be used to adapt cognitive training models developed for other populations to MS patients. This can help in improving cognitive functions such as memory and attention, which are often impaired in MS[3].
2. **Predictive Modeling**:
    1. Transfer learning can enhance predictive models for disease progression in MS by leveraging data from related neurological conditions. This can lead to more accurate predictions and personalized treatment plans[4].

Data Generation and Capture

- **Smart Wearables and Phones:**
  - Capturing data through neurological anomalies and disorders
  - Insights for digital rehabilitation

1. **Publicly Available Datasets**

1. *MIT-BIH Atrial Fibrillation Database [15]:* This dataset includes 25 long-term ECG recordings of human subjects with atrial fibrillation, primarily paroxysmal. The AI models can be trained to analyze the heart's electrical activity and detect abnormal heart rhythms in real-time using physiological signals, such as ECG. .

2. *Multiple Sclerosis Core Dataset [16]:* This core dataset for multiple sclerosis (MS) consists of 44 variables in eight categories, covering demographics, comorbidities, disease history, MRI results, and treatment data. The dataset is highly useful for modeling disease progression and creating personalized rehabilitation plans. It allows us to assess both the motor and cognitive impairments caused by MS and enables the development of AI-based algorithms for predicting relapses and planning long-term rehabilitation.

3. *Stroke Prediction Dataset [17]:* This dataset provides 11 clinical features for predicting stroke events. It is a vital resource for training models to detect early signs of stroke and predict future stroke risks. The features include common stroke risk factors such as hypertension, diabetes, and heart disease, allowing our models to make informed predictions and offer preventive interventions.

VR and AR

VR (Virtual Reality): Immerses users in a fully virtual environment, usually through headsets, isolating them from the real world to interact with a simulated space.

AR (Augmented Reality): Enhances the real-world environment by overlaying digital information, often using smart glasses or headsets.

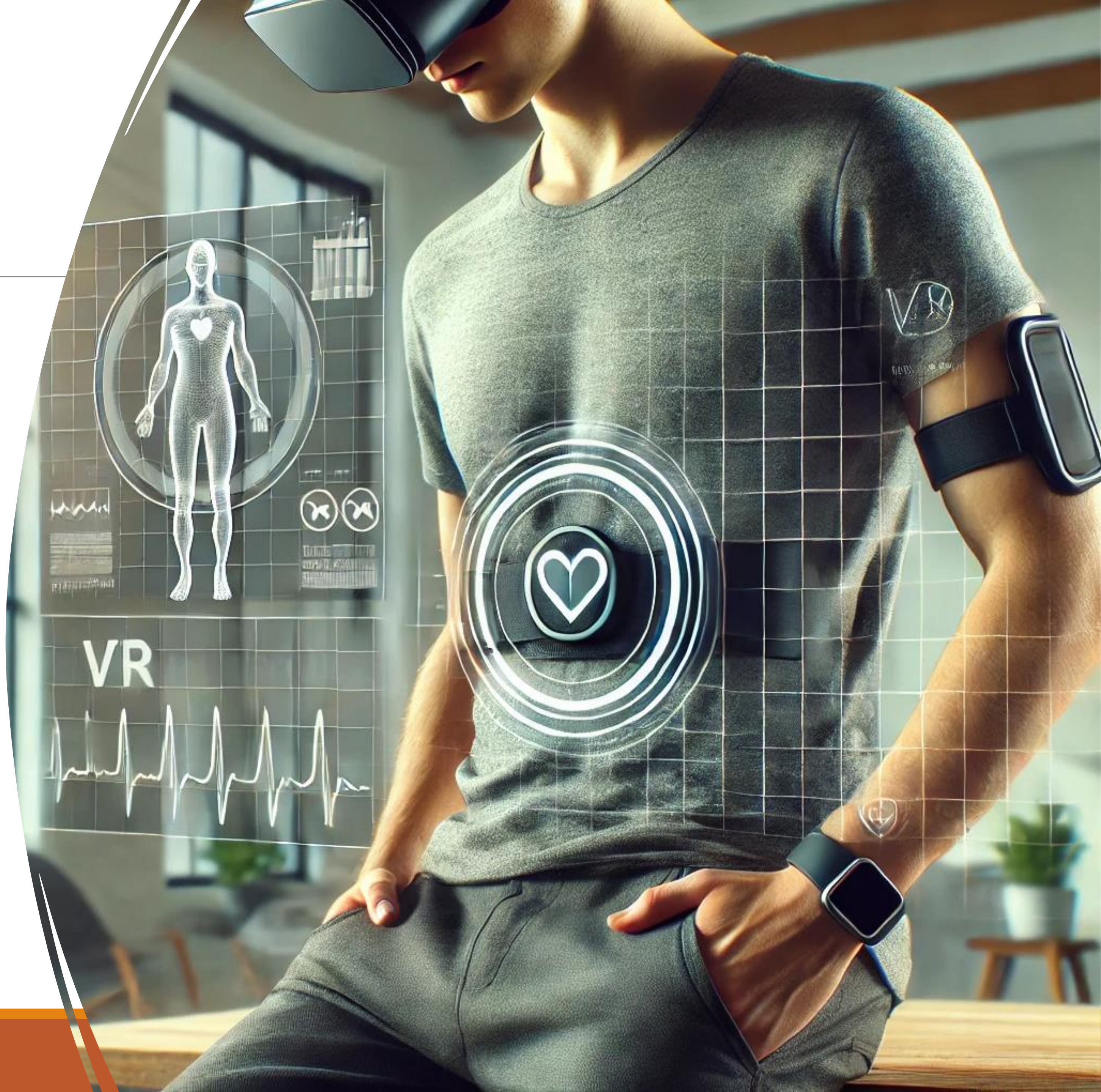
Advantages of AR/VR for Stroke and MS Diagnosis & Monitoring

Enhanced Motion Capture

- Like wearables, AR/VR devices are equipped with motion sensors to capture movements for diagnosis and monitoring.

Head-Mounted Benefits

- Head-mounted AR/VR can monitor subtle head movements and access sensors like EEG for early detection.



Advantages of AR/VR for Stroke and MS Diagnosis & Monitoring

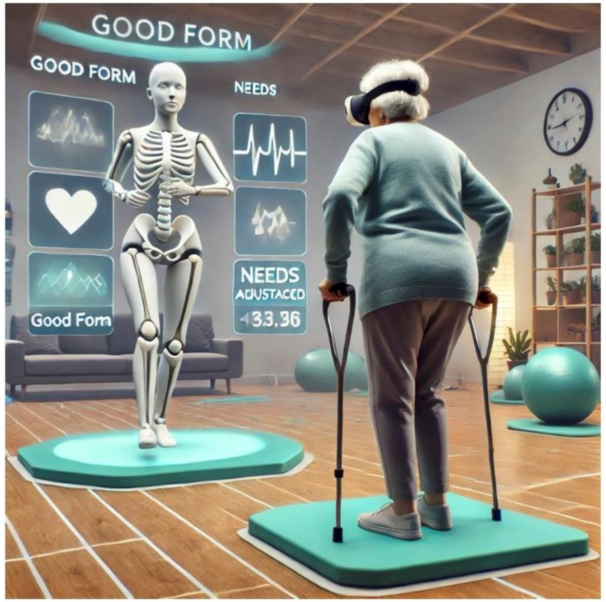
Data Visualization

- Unlike wearables, AR/VR can visualize data directly in front of users, offering real-time insights into body and brain health.

Rehabilitation Support

- Provides virtual avatars for guided exercises and instant feedback, encouraging proper movement and building patient confidence.

aring VR Headset for Rehabilitation



Rehabilitation Recommendation Assistant in VR environment

AR/VR in Stroke and MS

Stroke

1. **Motor Function Rehabilitation**: VR and AR are used to create immersive environments where stroke patients can practice motor skills. These environments provide real-time feedback and can be tailored to the patient's specific needs, enhancing the recovery of upper and lower limb functions[1,2].

2. **Cognitive Rehabilitation**: VR can simulate real-life scenarios to help stroke patients improve cognitive functions such as memory, attention, and problem-solving skills. This immersive approach makes therapy more engaging and effective[3].

3. **Balance and Gait Training**: AR and VR systems can be used to improve balance and gait in stroke patients. These systems provide visual and auditory feedback to help patients correct their movements and improve their walking patterns[4].

4. **Home-Based Rehabilitation**: VR and AR enable home-based rehabilitation, making therapy more accessible and convenient. Patients can perform exercises at home while being monitored remotely by healthcare providers[4].

Multiple Sclerosis (MS)

1. **Upper Limb Rehabilitation**: VR is used to enhance upper limb motor function in MS patients. Immersive VR environments make repetitive exercises more engaging, which can lead to better adherence and outcomes[5,6].

2. **Balance and Gait Improvement**: Similar to stroke rehabilitation, VR and AR are used to improve balance and gait in MS patients. These technologies provide a safe and controlled environment for patients to practice and improve their mobility[4].

3. **Cognitive and Mood Enhancement**: VR therapy has shown promise in improving cognitive functions and mood in MS patients. While more research is needed, initial studies suggest that VR can help with cognitive training and emotional well-being[7].

4. **Patient Engagement and Motivation**: The interactive nature of VR and AR makes therapy more enjoyable and motivating for patients. This increased engagement can lead to better adherence to rehabilitation programs and improved outcomes[6].

Augmented and Virtual Reality

- **Applications:**
  - Cognitive therapy
  - Psychiatric assessments
  - Rehabilitation

AR/VR Environment

Development Tools and SDKs

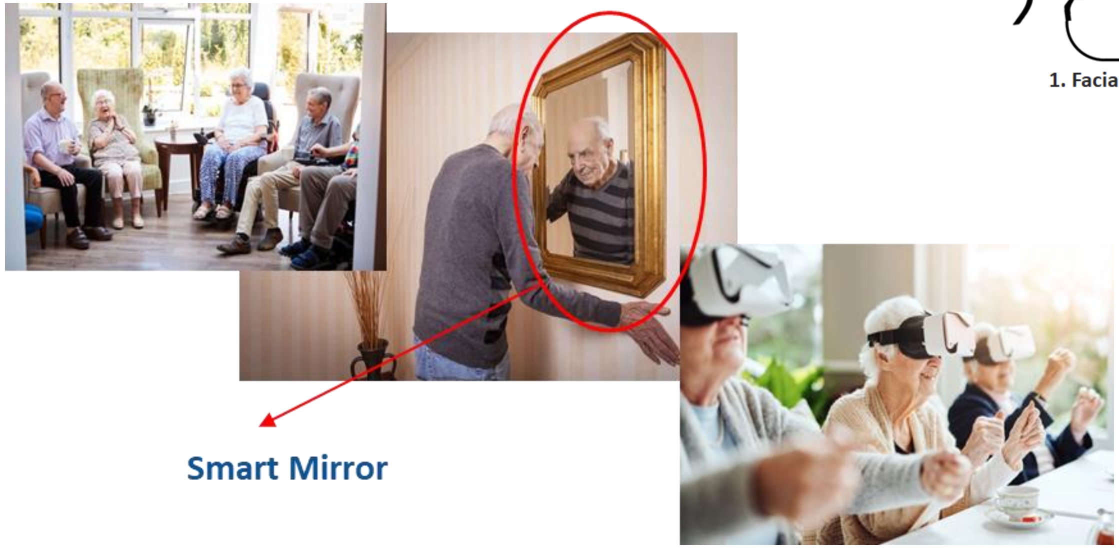
- **Unity**: A popular game engine used for creating both AR and VR applications. Supports a wide range of platforms.
- **Unreal Engine**: Known for its high-quality graphics
- **ARKit**: Apple's framework for creating AR experiences on iOS devices.
- **ARCore**: Google's platform for building AR applications on Android.
- **Vuforia**: An SDK for creating AR applications that can recognize and track images and objects.

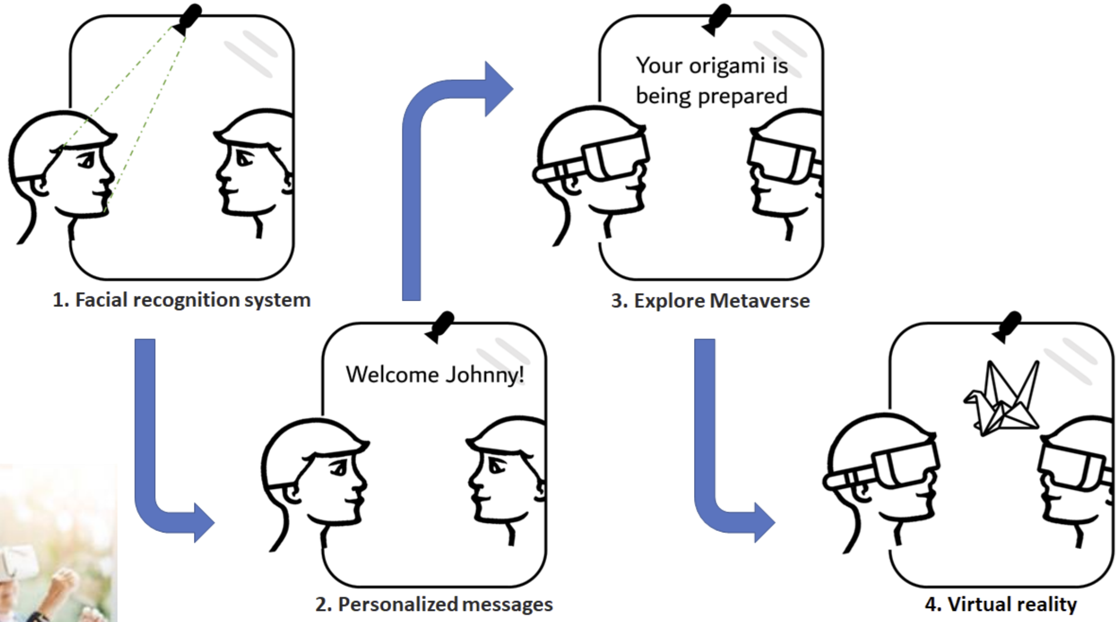
- **Programming Languages**
  - **C#**: Commonly used with Unity for AR/VR development.
  - **C++**: Often used with Unreal Engine for VR applications.
  - **JavaScript**: Used for web-based AR/VR applications.
  - **Python**: Sometimes used for scripting and rapid prototyping.
  - **Swift**: Used for ARKit development on iOS.

- **Hardware Components**
  - **Head-Mounted Displays (HMDs)**: Devices like Oculus Rift, HTC Vive, and Microsoft HoloLens.
  - **Motion Controllers**: Devices that allow users to interact with the virtual environment, such as Oculus Touch controllers.
  - **Tracking Systems**: Technologies that track the user's movements and position, such as the sensors used by HTC Vive.

Proof-of-Concept

- **Smart Diagnostics Enabled Mirror:**
  - Outline of the concept
  - Security issues in smart diagnostics





Thank you

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Some data sets on Strokes and MS

1. **Publicly Available Datasets**

1. *MIT-BIH Atrial Fibrillation Database [15]:* This dataset includes 25 long-term ECG recordings of human subjects with atrial fibrillation, primarily paroxysmal. The AI models can be trained to analyze the heart's electrical activity and detect abnormal heart rhythms in real-time using physiological signals, such as ECG. .

2. *Multiple Sclerosis Core Dataset [16]:* This core dataset for multiple sclerosis (MS) consists of 44 variables in eight categories, covering demographics, comorbidities, disease history, MRI results, and treatment data. The dataset is highly useful for modeling disease progression and creating personalized rehabilitation plans. It allows us to assess both the motor and cognitive impairments caused by MS and enables the development of AI-based algorithms for predicting relapses and planning long-term rehabilitation.

3. *Stroke Prediction Dataset [17]:* This dataset provides 11 clinical features for predicting stroke events. It is a vital resource for training models to detect early signs of stroke and predict future stroke risks. The features include common stroke risk factors such as hypertension, diabetes, and heart disease, allowing our models to make informed predictions and offer preventive interventions.

[15] Ary L Goldberger, Luis AN Amaral, Leon Glass, Jeffrey M Hausdorff, Plamen Ch Ivanov, Roger G Mark, Joseph E Mietus, George B Moody, Chung-Kang Peng, and H Eugene Stanley. Physiobank, physiotoolkit, and physionet: components of a new research resource for complex physiologic signals. circulation, 101(23):e215–e220, 2000.

[16] Tina Parciak, Lotte Geys, Anne Helme, Ingrid van der Mei, Jan Hillert, Hollie Schmidt, Amber Salter, Magd Zakaria, Alexander Stahmann, Pamela Dobay, et al. Introducing a core dataset for real-world data in multiple sclerosis registries and cohorts: Recommendations from a global task force. Multiple Sclerosis Journal, 30(3):396–418, 2024.

[17] Fedesoriano. Stroke prediction dataset, 2023. Accessed: 2023-09-21.