Decentralized AI

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Introduction

Dementia is a broad term that describes a decline in cognitive function severe enough to interfere with daily life. It refers to a collection of symptoms caused by various brain disorders rather than a single disease. Common symptoms include memory loss, difficulties with thinking, problem-solving, communication, and mood changes. There are several forms of dementia, with Alzheimer's disease being the most prevalent, often characterized by memory loss and confusion. Vascular dementia results from reduced blood flow to the brain, commonly following a stroke. Lewy body dementia is associated with abnormal protein deposits in the brain, while frontotemporal dementia affects behavior and language due to damage in the frontal and temporal lobes. Dementia is generally progressive, meaning symptoms worsen over time. While some treatments can help manage the symptoms, there is currently no cure for most types of dementia.

The COMFORTage project is at the forefront of innovation in dementia prevention and aging research. It pioneers new approaches to these challenges, with requirement analysis forming a key project component. This involves thoroughly examining current health interventions, digital health technologies, and personalized care frameworks. By integrating cutting-edge research, technological advancements, and clinical practice, COMFORTage aims to bridge the gap between scientific understanding and practical application in dementia care and aging. Its comprehensive approach informs future project strategies, positioning COMFORTage as a leader in the field.

Layer 1 PoA blockchains

In recent years, blockchain technology has gained significant attention and widely adopted across various industries. One of the critical challenges in blockchain networks is achieving consensus among the participants. The Proof of Authority (PoA) consensus algorithm is famous for its scalability and energy efficiency. This section presents state of the art in PoA blockchain networks and explores the utilization of 5G mobile connections as nodes in Layer 1 PoA blockchains for microtransactions. PoA, or Proof of Authority, is an algorithm used with blockchains and is responsible for delivering fast transactions through a consensus mechanism based on identity as a stake. VeChain, Reltime, and Xodex are the most notable PoA platforms.

The approved accounts in PoA-based networks corroborate the transactions and blocks. These are known as validators. The validators run the software and allow them to put the transactions in blocks. This process is automated, and there is no requirement for the validators to monitor the computers. Proof of Authority (PoA) is a consensus algorithm that relies on a set of trusted authorities or validators to validate transactions and create new blocks. Unlike Proof of Work (PoW) and Proof of Stake (PoS) algorithms, where participants compete or stake their tokens, PoA requires validators to be identified and authorized by the network. In PoA, block validators are known entities with known addresses and public keys, making it easier to identify bad actors.

Validators are typically selected based on their reputation, expertise, or stake in the network. Once authorized, a validator can participate in block creation and transaction validation. The consensus is achieved when most validators agree on the validity of transactions and the order of blocks. PoA consensus offers several advantages over other consensus algorithms. It eliminates the need for resource-intensive mining or staking, resulting in lower energy consumption and increased scalability. PoA also provides faster block confirmation times, making it suitable for applications that require high transaction throughput.

Project phase:

We divided it into two phase

- **Phase 1, our primary integration phase**, is a collaborative effort. It is pilot-driven, with the pilot actively interacting with the system. They will take the patient's record and push it into the blockchain through the decentralized application. Once all stakeholders can view the complete picture of the system, we can collectively navigate into the second phase, further strengthening our collaborative approach.
- **Phase 2 It is the advanced part of the project**. In this phase, we will determine the scope of automating the system. Let's say that every half an hour, we need to monitor the patient body temperature. Here, we can add a wearable with the patient's body to measure the temperature, and the system automatically pushes the device into the blockchain without a nurse or attendance. It is an example of IoT integration with blockchain. In the same way, if a doctor wants to track the patient's movement. We can install a surveillance camera to track the patient autonomously.

Phase 1

1. Finalise the Software Requirements Specification (SRS) document to ensure all requirements are well-defined and understood.
2. Local Development Environment Setup
   a. Establish the local development environment, including installing and configuring essential tools.
   b. Tools to be installed:
   c. Visual Studio Code (VS Code) - The primary code editor for writing, editing, and managing the project's codebase.
   d. MongoDB - A NoSQL database that stores and manages the project's configuration and structured data.
   e. Remix IDE - A browser-based IDE for writing, testing, and deploying Solidity smart contracts.
   f. Node.js - A runtime environment for building the backend server and handling server-side logic.

   g. Express.js (for backend processes) - A framework for structuring the backend, defining routes, and handling HTTP requests.

3. Front-End Framework Installation
   a. Install and configure front-end frameworks, ensuring compatibility:
   b. HTML, CSS, JavaScript (JS)
   c. , and React.js—Front-end Library.
   d. Ensure proper versioning to avoid conflicts during deployment.
4. IPFS Framework Installation and Configuration
   a. Install and configure the InterPlanetary File System (IPFS) framework for decentralised file storage.
5. Data Structure Design in Solidity
   a. Master the art of designing and implementing data structures using Solidity, a crucial skill tailored to project needs.
6. Configuration Table Setup in MongoDB
   a. Create and configure the necessary tables in the MongoDB database.
7. Smart Contract Development
   a. - Write and optimise smart contracts using Solidity.
   b. - Deploy, test, and debug smart contracts to ensure functionality and security.
8. Decentralized Application (dApp) Development
   a. - Develop the user interface for the decentralised application.
   b. - Ensure smooth communication between the DApp and blockchain.
9. IPFS Integration with DApp
   a. - Implement and verify communication between the DApp and the IPFS server.
10. Full Integration Testing
    a. - Conduct comprehensive integration testing to validate the seamless operation of all components.

Phase 2:

1) Sensor and Camera Installation
   - Install sensors and other solutions from the partners at the designated site to ensure accurate and reliable data capture.
   - Verify the proper functioning and calibration of all equipment.
2) Data Collection from the Pilot
   - Initiate data collection from the pilot phase.
   - Ensure the data captured is comprehensive and relevant for the subsequent AI model development.
3) Data Preparation
   - Clean and preprocess the collected data to make it suitable for AI model training.
   - Perform data normalization, feature extraction, and labeling as needed.
4) AI Model Creation (Potential MSc Project)
   - Design the AI model architecture tailored to the project's specific requirements.
   - Define the necessary algorithms and techniques for optimal model performance.
5) AI Model Training (Potential MSc Project)
   - Train the AI model using the prepared dataset.
   - Apply appropriate training methods to achieve high accuracy and generalization.
6) Model Testing (Potential MSc Project)
   - Conduct rigorous testing of the AI model to assess its performance on unseen data.
   - Identify and address any issues or inaccuracies.
7) Model Performance Metrics Calculation.
   - Calculate performance metrics such as accuracy, precision, recall, F1 score, and others to evaluate the AI model's effectiveness.
   - Document the results and use them to refine the model if necessary.

8) AI Integration with Front-End (Potential MSc Project).Seamlessly integrate the AI model into the front-end application.Ensure that the AI-driven features are user-friendly and responsive.

9) Final Submission

   - Prepare and submit the final version of the project, ensuring all deliverables are met and documented.

10) User Feedback Collection.

   - Gather user feedback to evaluate the system's performance and satisfaction.Collect detailed feedback through surveys, interviews, and direct user interaction.

11) System Tuning Based on Feedback.

   - Analyse the feedback received and implement necessary adjustments to improve system performance. Focus on addressing any issues raised by users and enhancing overall functionality.

12) Ongoing System Updates.

   - Regularly update the system to incorporate new features, improvements, and optimisations. Ensure the system remains up-to-date and continues to meet user needs over time.

Block diagram

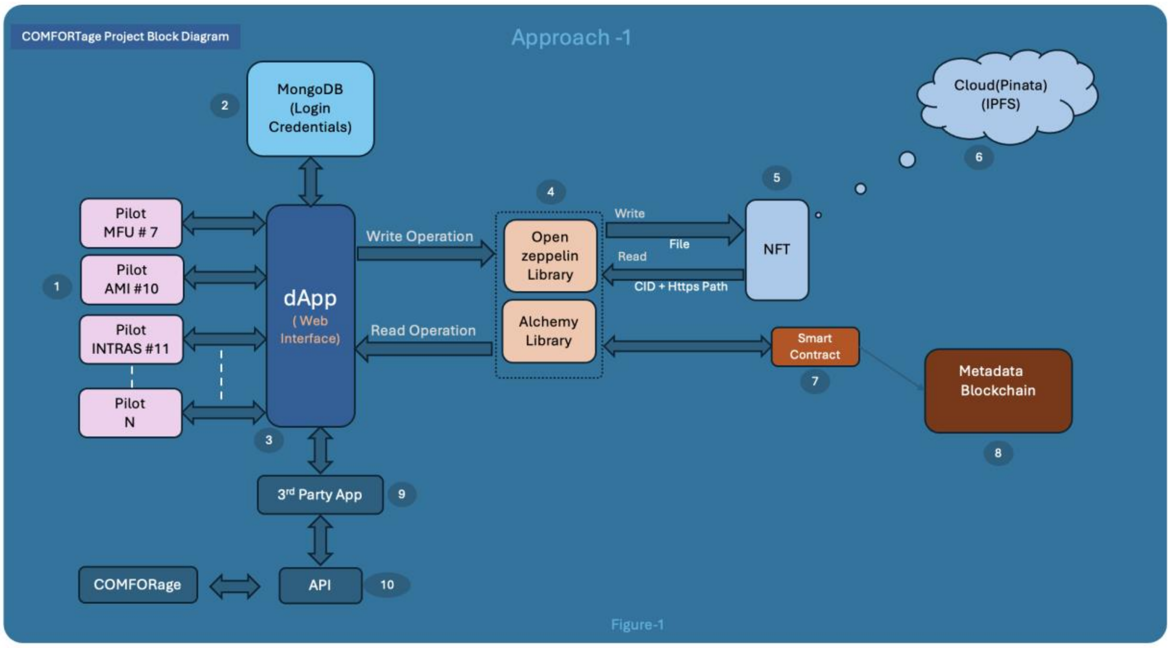


Figure 1:Project Block Diagram

Description

This diagram appears to outline the architecture of a decentralized application (Dapp) that interacts with multiple components, including MongoDB, smart contracts, third-party apps, and an API. Here's a detailed breakdown of the various components in the image, based on the labeled numbers:

1. Pilots (MFU #7, AMI #10, INTRAS #11, Pilot N):
    - These seem to represent different pilots or client modules that interact with the Dapp. Each pilot module likely represents a distinct user or system using the application. These modules feed data into the Dapp.
2. MongoDB (Login Credentials):
    - The Dapp connects to MongoDB to handle login credentials or

Figure 2:Project Block Diagram

other data storage needs. MongoDB stores and retrieves data files, potentially for user management or transaction logs.
3. Dapp (Web Interface):

  - The core of the system is the Dapp, which serves as the main interface for users to interact with the blockchain, smart contracts, and other parts of the system.
  - It interacts with various pilots, MongoDB, smart contracts, and external third-party apps.
  - The Dapp likely facilitates both read and write operations to the blockchain and MongoDB.
4. Library Framework (OpenZeppelin, Alchemy): (Frame around)
   - The Dapp uses two libraries/frameworks for blockchain interaction:
     - OpenZeppelin: A widely-used framework for deploying secure smart contracts.
     - Alchemy: A blockchain infrastructure provider that helps developers build scalable Dapps. This is likely used to interface with the blockchain for transaction management and retrieving metadata from smart contracts.
5. NFT:
   - NFTs (Non-Fungible Tokens) are unique digital assets representing ownership of a specific item or piece of content on a blockchain, such as art, music, or virtual real estate.
   - Unlike cryptocurrencies, each NFT has a distinct value and cannot be exchanged one-to-one. They are typically built on Ethereum using standards like ERC-721 or ERC-1155.
   - NFTs enable artists and creators to monetize their work through direct sales or royalties from secondary sales. Their ownership and transaction history are transparently recorded on the blockchain, ensuring authenticity and provenance.
6. Cloud IPFS(Pinata):
   - Decentralized Storage: Cloud IPFS (InterPlanetary File System) services like Pinata provide decentralized storage solutions, allowing users to store and access files distributed across a peer-to-peer network instead of relying on a centralized server.
   - Data Persistence: Pinata helps ensure the persistence of data on the IPFS network by "pinning" content, meaning it keeps the files available and accessible over time, making it ideal for projects that need reliable data availability.
   - IPFS Integration: Pinata integrates directly with the IPFS protocol, making it easier for developers to store, retrieve, and manage content such as NFTs, media files, and other decentralized applications through a user-friendly interface and API.
   - Scalability and Performance: By using a service like Pinata, developers can scale their storage needs without worrying about infrastructure maintenance, benefiting from high availability and faster retrieval times for their data on IPFS.

    - Access Control and Security: Pinata provides tools to manage file access and offers a secure environment for storing sensitive content on IPFS, ensuring that only authorized users can interact with the stored data.
7. Blockchain:
    - This represents the final storage and execution layer for transactions. The blockchain interacts with the smart contracts, ensuring that any interactions done via the Dapp are securely committed.
8. Smart Contract:
    - The smart contract is a core element connected to the Dapp. It likely contains the business logic governing blockchain transactions. The Dapp reads metadata from the smart contract and sends write operations to it, which eventually get committed to the blockchain.
9. 3rd Party App:
    - The Dapp has integration with an external third-party application. This could be an analytics platform, payment processor, or another external service providing additional functionality.
10. API:
    - The Dapp also interacts with an external API, likely to fetch data or communicate with other systems.

Workflow

When deploying the system for user access, the process follows these steps:

1. User Sign-Up:
    - The user initiates interaction by accessing the web interface and creating an account.
    - Once the account is created, an admin receives a notification for approval. Upon approval, the user gains access to the system's operations.
2. Database Management:
    - User credentials, access rights, and project settings are securely stored in a central database.
3. Decentralised Application (Dapp):
    - The Dapp manages user interactions within the system, ensuring seamless communication between the user interface and backend processes.
4. Metadata and Blockchain Integration:
    - The Dapp sends the file to the IPFS cloud upon data entry, retrieving a content ID (CID) and file URL.
    - This metadata is then forwarded to smart contracts responsible for writing it into the blockchain.

5. Smart Contracts and NFTs:
    - Files stored within IPFS are assigned unique identifiers as Non-Fungible Tokens (NFTs), ensuring that each document is immutable and easily retrievable.
6. Third-Party Integration:
    - External applications can interact with the system, thoroughly verifying all content before integration.

When the system is deployed and submitted for the user's access, it is entirely blank. We provide a web interface for the user to interact with.

- At first, the user opens the web interface and creates an account using the "Sign up" button. The admin will receive a mail. Once the admin is approved using the admin panel, the user can access the operation. In the figure, mark-1 is the user. We showed the three pilots here. In a real scenario, N users can access the system.
- Mark-2 is the database storing user credentials, access rights, and different project-related settings.
- The mark-3 is the decentralised application(Dapp). The user interaction is handled by a decentralised application that resides inside the cloud server.
- The mark-4 is the collection of the library framework, which is responsible for flawlessly communicating with blockchain and IPFS. When a user wants to write data for the blockchain, the Dapp processes it. At first, it sends the file to the cloud IPFS and gets the content ID(CID) and file URL path. Then, Dapp created a JSON structure called metadata. The metadata is sent to the smart contracts. Then, the metadata is written into the blockchain memory.
- Mark-5 is the Non-Fungible Token(NFT). All files stored inside the IPFS are nonfungible. Every file holds a unique ID. Users can fetch this file by sending the unique document identifier from the IPFS.
- The Mark-6 is the IPFS, which resides inside the cloud interface. Here, we showed one website, Pinata, a popular IPFS cloud platform. Other popular platforms are available where we can store our files decentralised.
- Mark-8 is a smart contract written using Solidity language. It is responsible for receiving metadata from the user and writing to the blockchain. When the user wants some information, it fetches the data from the blockchain memory. The Dapp then displays it to the user interface.
- Mark-7 is the blockchain; it is EVM-compatible. Our programming language is Solidity, which can only be deployed inside the blockchain.
- Mark-9 is the third-party app provider module that handles all communication outside the system. All received content is first verified and thoroughly checked for authenticity. Once it is passed, the information is provided to the client.

- Mark-10 is the list of APIs facilitating various query functions to send/receive the data.

Smart Contract:

List of variables

This is list of variable of the questionary to the pilots.

List of Data Inputs for Dementia Analysis	MFU # 7	AMI #10	INTRAS #11	MUL #5
Personal Medical Records.				
1. Personal Information:				
- Name		x	X	X
- Date of Birth	X	x	X	X
- Gender	X	x	X	X
- Contact Details		x		X
2. Medical History:				
- Past Medical Conditions	X	x	X	X
- Surgeries		x		
- Allergies				
- Chronic Diseases	X	x	X	X
3. Medications:				
- Current Medications	X	x	X	X
- Past Medications		x	X	X
- Dosages	X	x	X	X
- Prescribing Doctors				
4. Diagnoses:				
- Details of Dementia Diagnosis			X	X
- Type of Dementia	X		X	X
- Stage and Progression	X	x	X	X

Clinical Data:				
5. Lab Results:				
- Blood Tests	X			X
- Imaging Results (MRI, CT scans)				X
- Genetic Tests				
6. Vital Signs:				
- Blood Pressure	X	x	X	X
- Heart Rate	X	x	X	X
- Temperature	X		X	X
- Weight	X	x	X	X
7. Clinical Notes:				
- Doctor's Notes				
- Observations				
- Treatment Plans				X
Treatment Plans:				
8. Therapies:				
- Cognitive Therapies	X			X
- Physical Therapies	X	x		X
- Occupational Therapies	X			X
9. Care Plans:				
- Home Care Details				X
- Nursing Care	X			X
- Assisted Living Arrangements	X			X

10. Lifestyle Recommendations:				
-Diet				X
- Exercise		x		X
- Other Lifestyle Modifications				X
Consent and Permissions:				
11. Patient Consent:				
- Records of Patient Consent for Treatments		x	X	X
- Data Sharing	X	x	X	X
- Research Participation	X	x	X	X
12. Access Permissions:				
- Control Over Who Can Access, View, and Modify Records	X		X	
Genomic Data:				
13. Genetic Information:				
- Data from Genetic Testing				
- Predisposition to Dementia				
14. Family History:				
- Information about Dementia in Family Members		x	X	
Research Data:				
15. Clinical Trials:				
- Data from Clinical Trials Involving Dementia Patients	X		X	

16. Study Results:				
- Findings from Studies and Research Involving Patient Data	X		X	
Insurance and Billing Information:				
15. Dental History:				
- Conditions	X			
16. Activity Logs:				
- Data from Fitness Trackers or Apps (Steps Taken, Exercise Routines)	X	x		
- Sleep Patterns	X			
17. Exercise Plans:				
- Personalized Exercise Recommendations		x		
- Progress Tracking		x		
18. Food Intake Logs:				
- Records of Daily Food Intake		x		
19. Living Conditions:				
- Information about the Patient's Living Environment	X		X	
20. Social History:				
- Lifestyle Factors	X		X	
- Employment Status		x	X	
- Social Support Networks			X	
21. Rehabilitation Plans:				
- Detailed Plans for Physical, Occupational, and Speech Therapy		x		
22. Progress Reports:				
- Regular Updates on the Patient's Progress in Rehabilitation Programs		x		
23. Device Readings:				

- Data from Personal Health Devices (Blood Glucose Monitors, Heart Rate Monitors, Wearable ECGs)	X			
24. Prescription History:				
- Dosages		x		
- Durations		x		

Data structure

```
// SPDX-License-Identifier: MIT
pragma solidity ^0.8.0;

import "@openzeppelin/contracts/access/AccessControl.sol";
import "@openzeppelin/contracts/security/ReentrancyGuard.sol";

contract COMFORTage is AccessControl, ReentrancyGuard {
    bytes32 public constant ADMIN_ROLE = keccak256("ADMIN_ROLE");
    bytes32 public constant PILOT_ROLE = keccak256("PILOT_ROLE");

    struct User {
        string name;
        bool isApproved;
        uint256 createdAt;
    }

    struct PatientData {
        string ipfsHash;
        uint256 timestamp;
    }

    mapping(address => User) public users;
    mapping(address => mapping(string => PatientData)) private patientRecords;

    event UserRegistered(address indexed userAddress, string name);
    event UserApproved(address indexed userAddress);
    event DataStored(address indexed pilotAddress, address indexed patientAddress, string dataType);

    constructor() {
        _grantRole(DEFAULT_ADMIN_ROLE, msg.sender);
        _grantRole(ADMIN_ROLE, msg.sender);
    }

    function registerUser(string memory _name) external {
        require(users[msg.sender].createdAt == 0, "User already registered");
        users[msg.sender] = User(_name, false, block.timestamp);
        emit UserRegistered(msg.sender, _name);
    }

    function approveUser(address _userAddress) external onlyRole(ADMIN_ROLE) {
        require(users[_userAddress].createdAt != 0, "User not registered");
        require(!users[_userAddress].isApproved, "User already approved");
        users[_userAddress].isApproved = true;
        _grantRole(PILOT_ROLE, _userAddress);
        emit UserApproved(_userAddress);
    }
```

```
    function storePatientData(address _patientAddress, string memory _dataType, string memory _ipfsHash)
        external
        onlyRole(PILOT_ROLE)
        nonReentrant
    {
        require(bytes(_ipfsHash).length > 0, "IPFS hash cannot be empty");
        patientRecords[_patientAddress][_dataType] = PatientData(_ipfsHash, block.timestamp);
        emit DataStored(msg.sender, _patientAddress, _dataType);
    }

    function getPatientData(address _patientAddress, string memory _dataType)
        external
        view
        returns (string memory ipfsHash, uint256 timestamp)
    {
        require(hasRole(PILOT_ROLE, msg.sender) || hasRole(ADMIN_ROLE, msg.sender), "Unauthorized");
        PatientData memory data = patientRecords[_patientAddress][_dataType];
        return (data.ipfsHash, data.timestamp);
    }

    function isUserApproved(address _userAddress) external view returns (bool) {
        return users[_userAddress].isApproved;
    }
}
```

Explanation:

1. **Structs:** Each section of the medical record (Personal Information, Medical History, Medications, etc.) is defined as a struct to logically group related data.
2. **Arrays:** Some fields like pastMedicalConditions or medications are arrays, as they can have multiple entries over time.
3. **Mapping:** The mapping(address => MedicalRecord) allows storing medical records for multiple patients, where each patient's address serves as the key.
4. **Access Control:** Access permissions are included to track who can view or modify the patient's data, making the system compliant with privacy regulations.
5. **Flexible Data Handling:** Arrays like medications, clinical trials, and progress reports allow for a dynamic list of entries, as these fields will grow over time with new data.

This data structure is designed to securely and decentralized handle the complexity of medical records, which fits well within a smart contract environment.

Decentralized Application(Dapp)

The figures below depict the design of the Dapp interface. The programmer can improve it, and the information below is for their reference only.

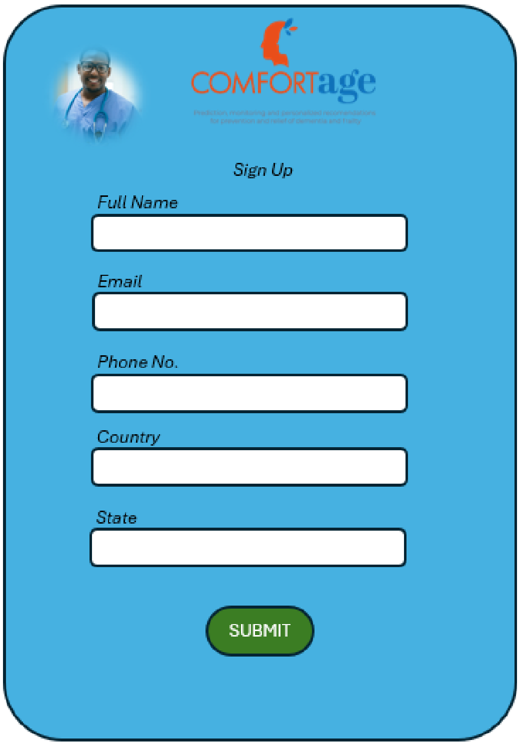
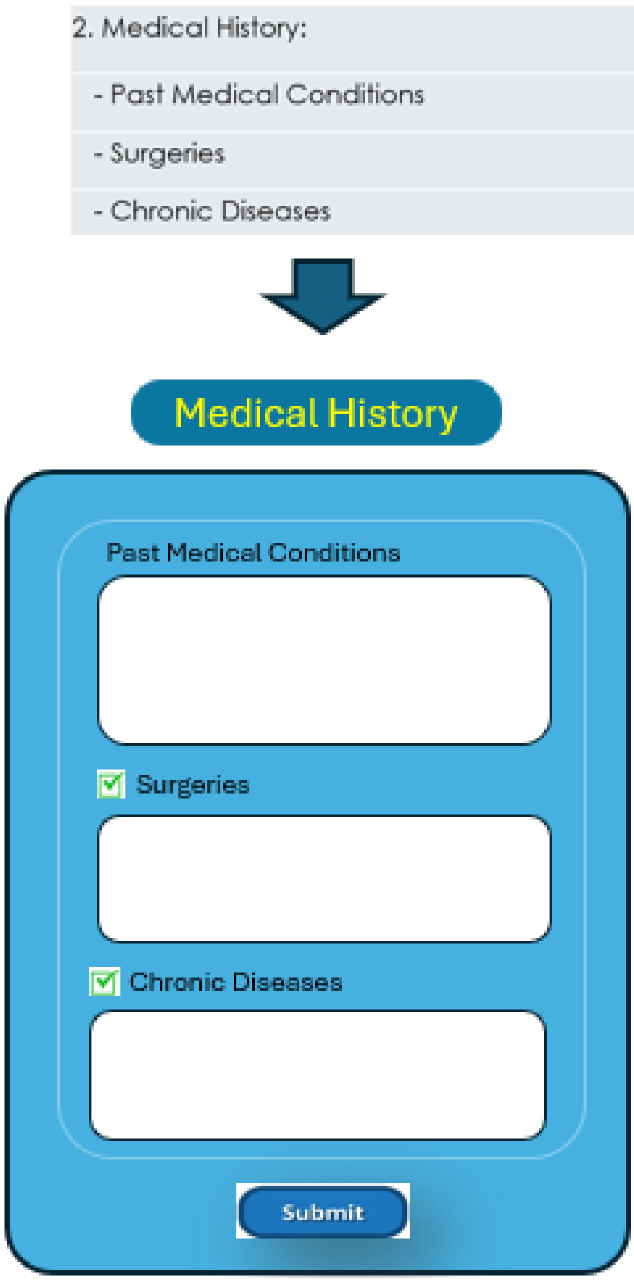


Figure 3: Sign up page

Figure 3: Sign up page

1. Personal Information:
   - Name
   - Date of Birth
   - Gender
   - Contact Details

Figure 5: Personal information Page


2. Medical History:
- Past Medical Conditions
- Surgeries
- Chronic Diseases
Medical History
Past Medical Conditions
Surgeries
Chronic Diseases
Submit

3. Medications:
- Current Medications
- Past Medications
- Dosages

Medications

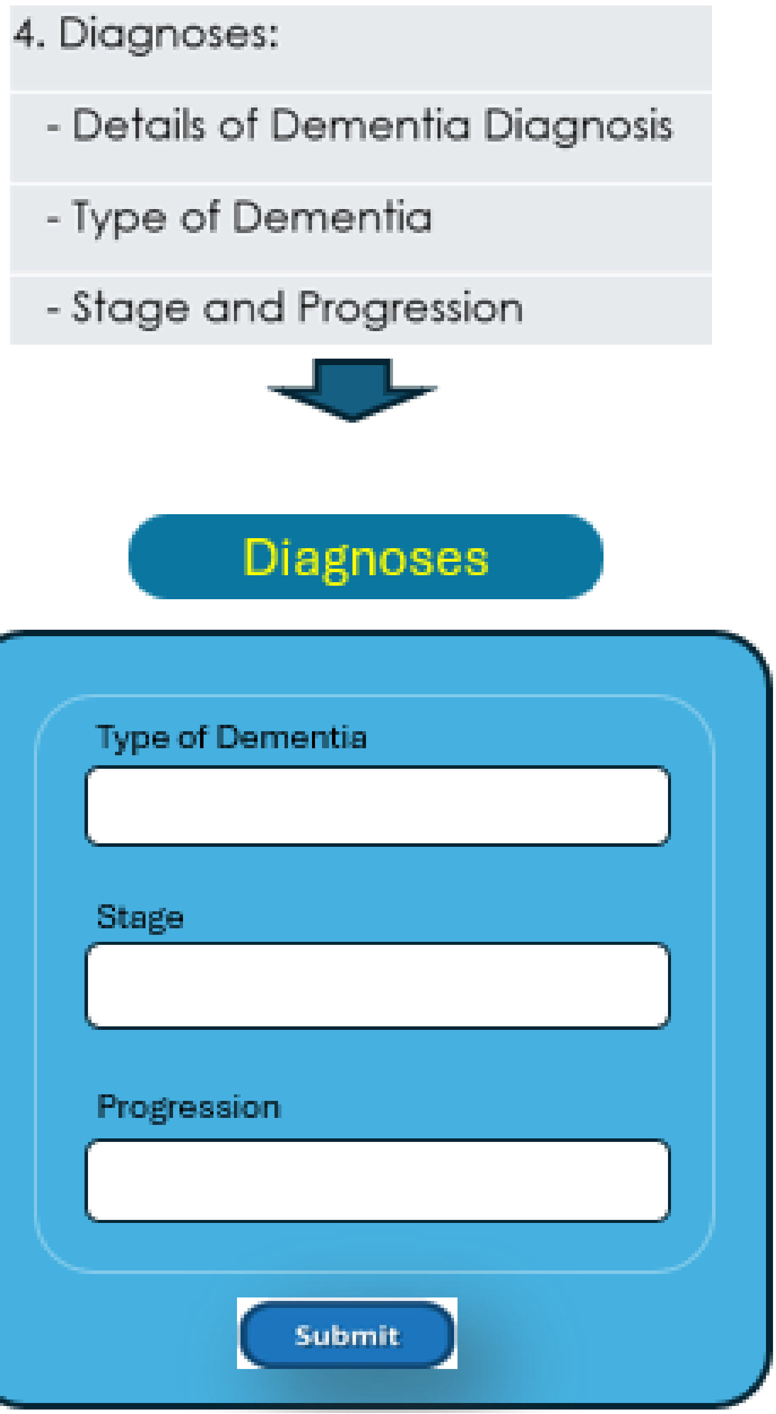
Current Medications

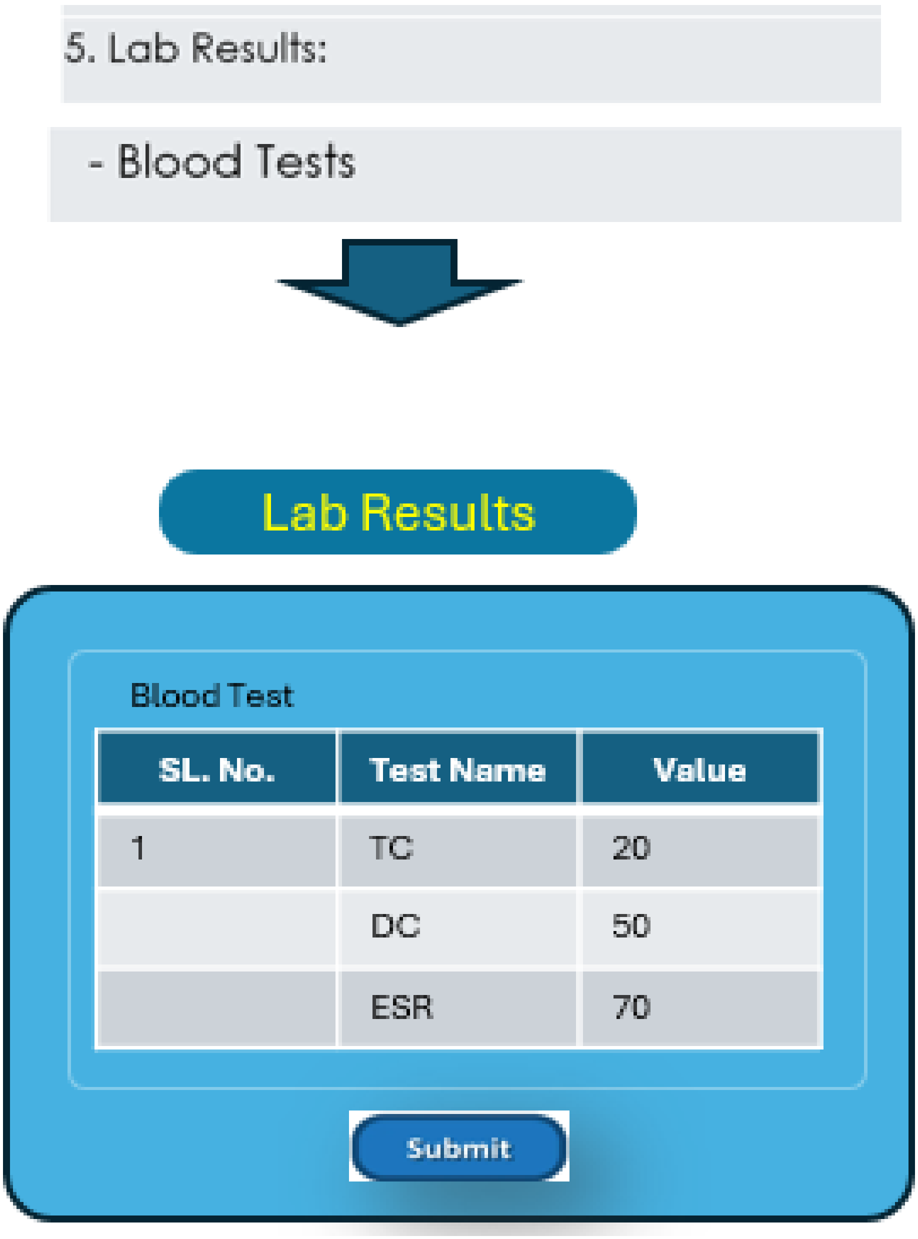
SL. No.	Medicine	Dose	Frequency	Duration
1	Xyz	3.5 ml	BD	5 days

Past Medications

SL. No.	Medicine	Dose	Frequency	Duration
1	Xyz	3.5 ml	BD	5 days

Submit


4. Diagnoses:
- Details of Dementia Diagnosis
- Type of Dementia
- Stage and Progression
Diagnoses
Type of Dementia
Stage
Progression
Submit


5. Lab Results:
- Blood Tests
Lab Results
Blood Test
SL. No.
Test Name
Value
1
TC
20
DC
50
ESR
70
Submit

6. Vital Signs:

- Blood Pressure
- Heart Rate
- Temperature
- Weight

Vital Signs

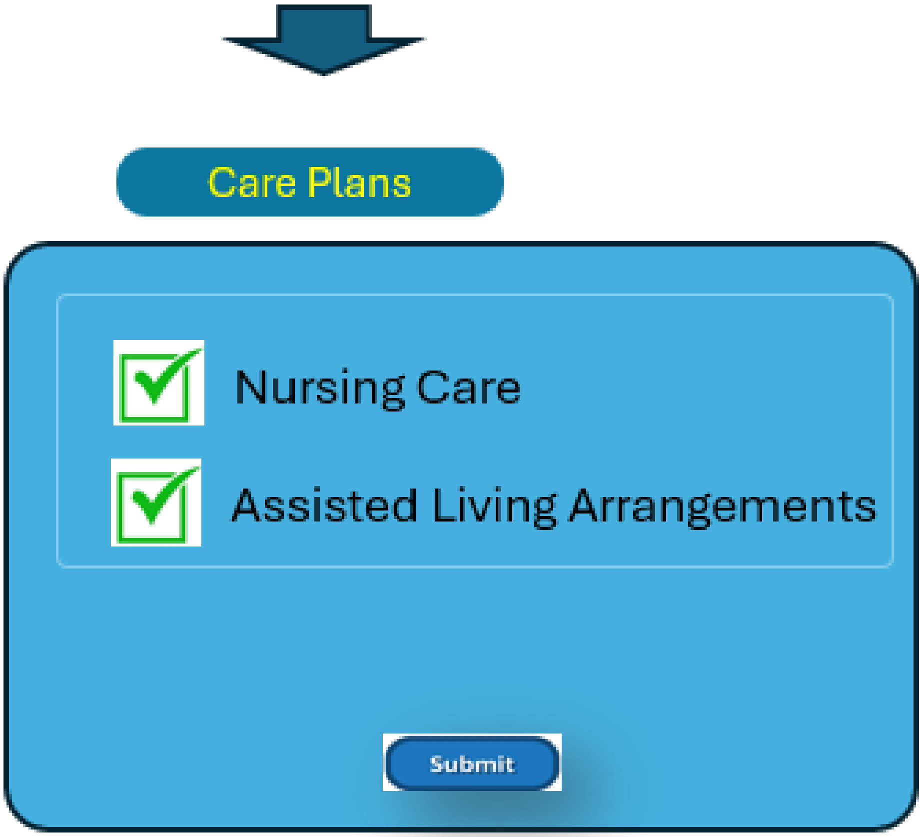
Sl. No.	Parameter	Value
1	BP(SYS)	120
2	BP(DYA)	80
3	Heart Rate	72
4	Temperature	98.5
5	Weight	86 Kg

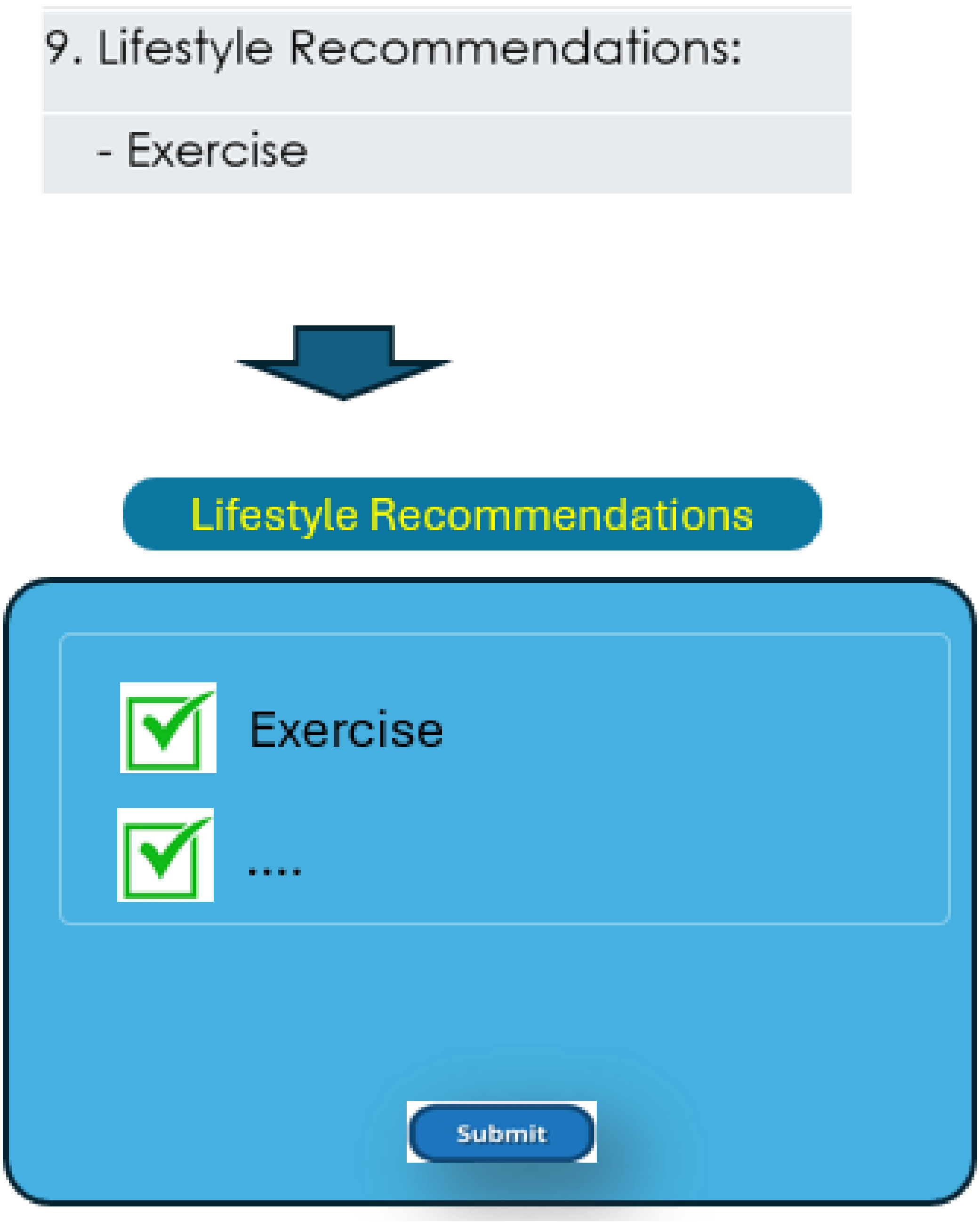
Submit


7. Therapies:
- Cognitive Therapies
- Physical Therapies
- Occupational Therapies
Therapies
Cognitive Therapies
Physical Therapies
Occupational Therapies
Submit

8. Care Plans:

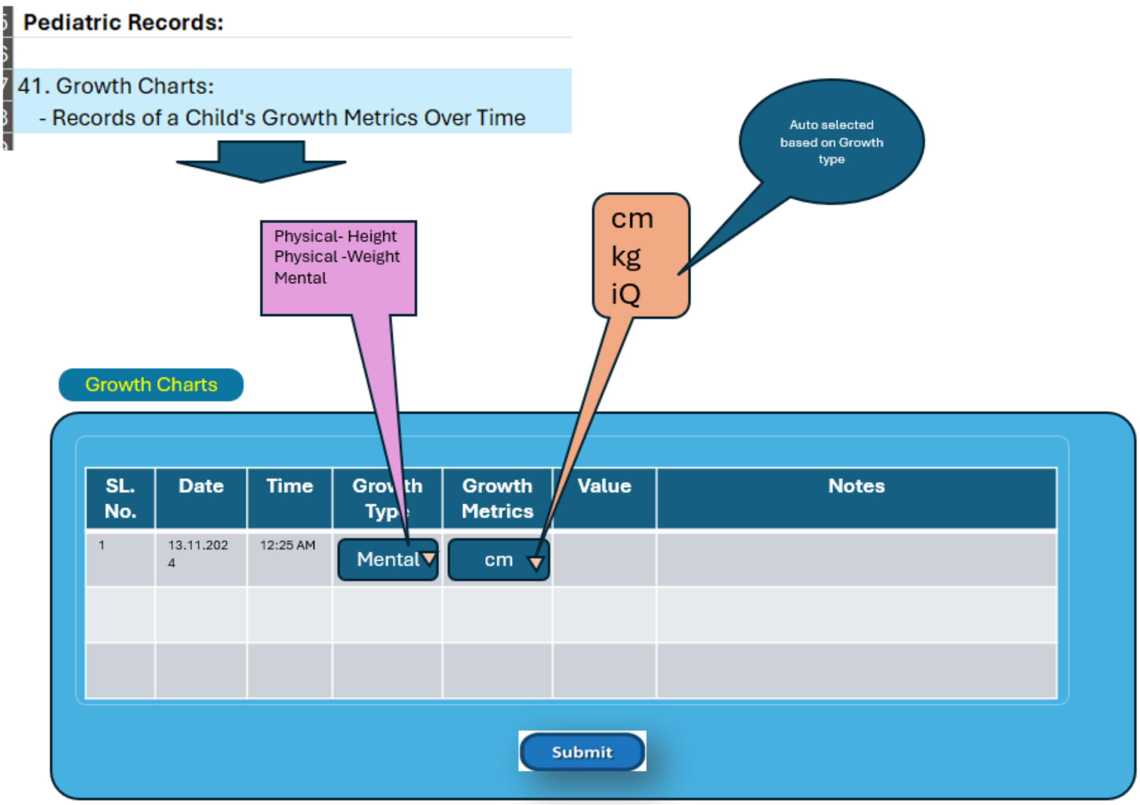
- Nursing Care
- Assisted Living Arrangements



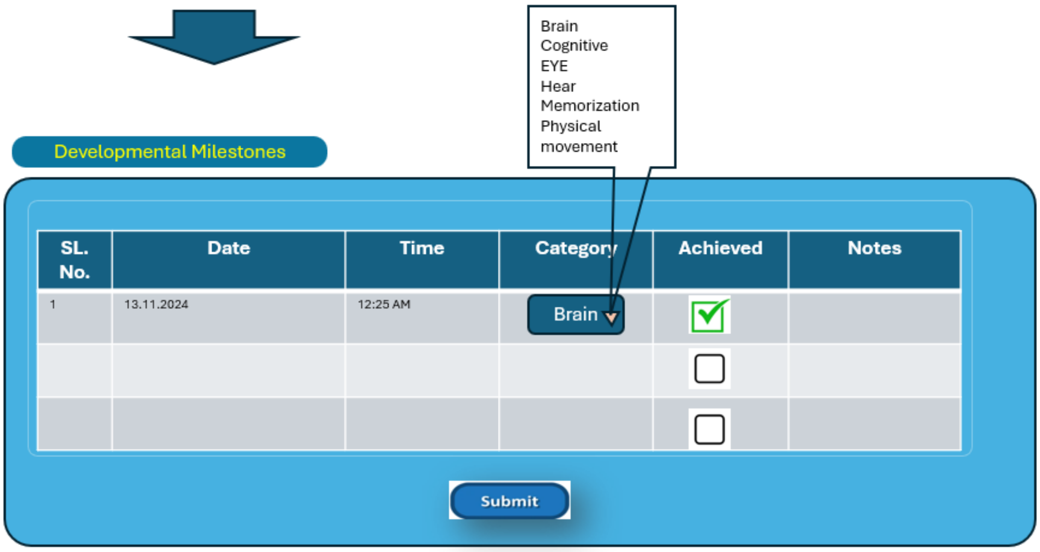

9. Lifestyle Recommendations:
- Exercise
Lifestyle Recommendations
Exercise
....
Submit

10. Patient Consent:

- Records of Patient Consent for Treatments
- Data Sharing
- Research Participation


Pediatric Records:
41. Growth Charts:
- Records of a Child's Growth Metrics Over Time
Physical- Height
Physical -Weight
Mental
cm
kg
iQ
Auto selected based on Growth type
Growth Charts
SL. No.
Date
Time
Growth Type
Growth Metrics
Value
Notes
1
13.11.2024
12:25 AM
Mental
cm
Submit

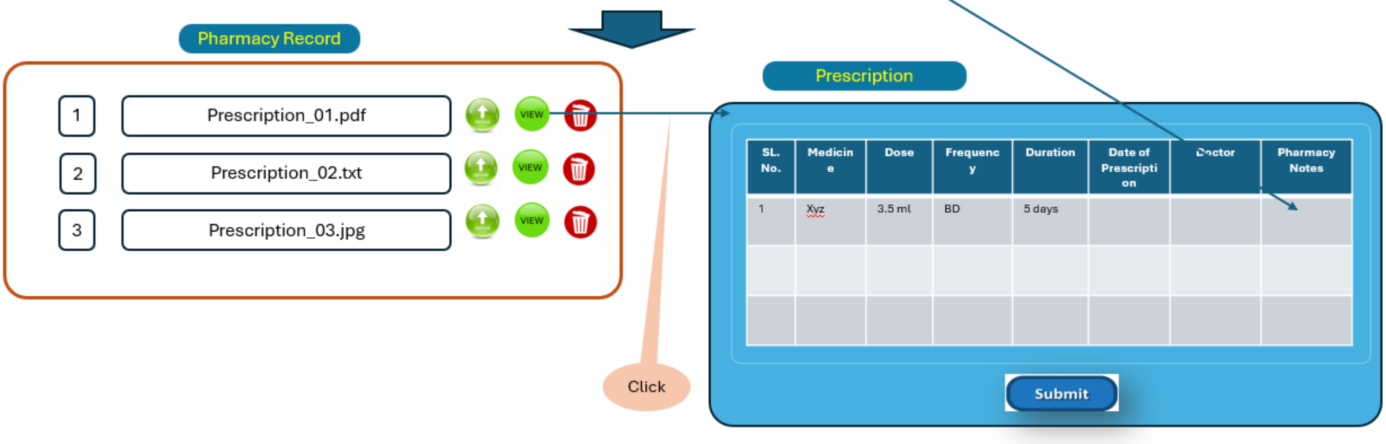
42. Developmental Milestones:
- Notes on Achieving Key Developmental Milestones

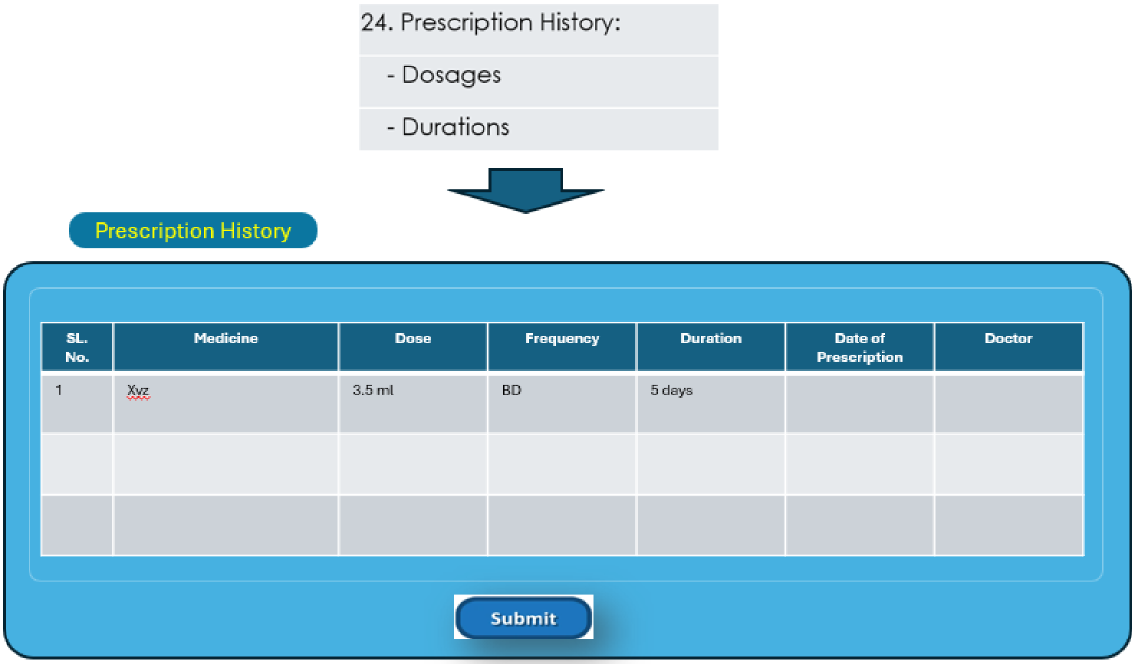


Pharmacy Records:

43. Prescription History:
- Comprehensive List of Prescriptions Filled
- Dosages
- Durations

44. Pharmacy Notes:
- Additional Notes from Pharmacists Regarding Medication Usage and Interactions





Zero Trust System

Zero Trust is a security model and framework that assumes threats exist inside and outside a network. Unlike traditional security models that rely on perimeter-based defenses (like firewalls), Zero Trust operates on the principle of "never trust, always verify." No user, device, or application is trusted by default, whether inside or outside the network. Access is granted based on a continuous verification process, which includes strict identity and access management (IAM), multi-factor authentication (MFA), and least-privilege access controls.

Fundamental principles of Zero Trust include:

1. **Verification of Identity**: Every user or device must be authenticated and authorized before accessing resources.
2. **Least Privilege**: Users and systems are only given access to the resources they need to perform their tasks, minimizing the risk of unauthorized access.
3. **Micro-Segmentation**: The network is divided into smaller zones, and access between them is tightly controlled, reducing the risk of lateral movement by attackers.
4. **Continuous Monitoring**: All network activity is logged and monitored in real time to detect suspicious behavior.
5. **Assumed Breach**: It is assumed that a breach may occur or already has, and security measures should be prepared to limit the potential damage.

Zero Trust is especially relevant for cloud environments, where users and devices are often distributed, and access can happen from various locations. It is designed to secure modern digital workplaces by addressing the security challenges of remote work, cloud services, and mobile devices.

AI Integration for Enhanced Healthcare Solutions

Overview:

Artificial Intelligence (AI) offers transformative capabilities in healthcare, particularly when integrated into systems like Reltime's blockchain-based solution. By leveraging AI, the project can significantly enhance predictive healthcare, automate analysis, and improve patient outcomes. This section outlines how AI will be integrated into the Reltime system to drive innovation in dementia care and broader healthcare applications.

Predictive Healthcare with AI

AI models can be developed using Google AI tools like TensorFlow to process large volumes of patient data captured by IoT devices (e.g., wearables for body temperature, heart rate, or movement tracking). These models can identify patterns and early warning signs of cognitive decline or medical emergencies in dementia patients, enabling healthcare providers to intervene earlier with more precise treatments.

Key Benefits:

• Early detection of deteriorating health conditions, enabling timely medical intervention.

• redictive models for assessing the progression of dementia, providing insights into when patients might need additional support or medical attention.

Automated Data Processing and Analysis

Using Natural Language Processing (NLP) from Google AI, patient records and medical histories can be automatically processed and analyzed. This automation reduces the workload on healthcare professionals and provides critical insights into patient care. By examining unstructured medical data, AI can detect trends and correlations that might otherwise be missed.

Key Benefits:

- Automatic processing of patient records, enhancing data accessibility and analysis.
- Advanced pattern recognition across historical patient data to recommend personalized care plans.

AI-Driven Personalization in Healthcare

Machine learning models can create personalized treatment and care recommendations by analyzing patient data across various metrics, such as vital signs, medical history, and real-time IoT data. These models will be integrated into the decentralized application (dApp), allowing healthcare providers to deliver highly personalized care for dementia patients and the elderly.

Key Benefits:

- Personalized therapy and care recommendations for each patient based on continuous data inputs.
- Integration of AI-driven insights directly into the dApp for real-time use by healthcare professionals.

AI for Security and Compliance

To strengthen the security of the system, AI-driven anomaly detection models can work alongside the Zero Trust architecture. Google AI's threat detection capabilities can monitor access patterns, identifying unusual or unauthorized attempts to access patient data, and immediately flagging potential breaches. This approach ensures compliance with healthcare regulations like GDPR.

Key Benefits:

- Real-time threat detection to protect sensitive healthcare data.
- AI-augmented security that complements the existing Zero Trust system, ensuring both compliance and safety.

1.1.1 Seamless AI-Blockchain Integration

AI models developed for healthcare diagnostics, predictive analysis, and patient monitoring will be seamlessly integrated with the blockchain system. Smart contracts on the blockchain will trigger AI-driven analyses at regular intervals or based on specific conditions (e.g., a patient's health metrics crossing a threshold). The immutable nature of the blockchain ensures that all AI-triggered actions are securely logged and verified.

Key Benefits:

- Automated, secure execution of AI-driven actions via smart contracts.
- Trustworthy and auditable records of AI recommendations and decisions within the blockchain.

Scalability and Optimization with Google AI

By using Google's AutoML and scalable cloud infrastructure, the AI components of the system can be continuously optimized. This will ensure the platform can handle large datasets efficiently, provide faster processing times, and maintain high levels of accuracy across multiple use cases, including real-time monitoring and historical data analysis.

Key Benefits:

• Scalable AI solutions that can handle the growing volume of patient and medical data.

• Ongoing optimization of AI models for improved accuracy and system performance.

Conclusion AI

By integrating AI into the Reltime healthcare solution, the project will enhance its ability to predict, personalize, and secure patient care. AI tools like those provided by Google will empower the platform to analyze vast amounts of healthcare data, automate decision-making processes, and maintain high standards of security, all within the decentralized framework of a blockchain-powered system. This approach positions Reltime as a leader in AI-driven healthcare innovation, particularly in the management of dementia and aging-related conditions.

This section outlines how AI can be used to improve both the technical and functional aspects of the proposed healthcare solution, making it more efficient, secure, and responsive to patient needs.

12. Future Work: Expanding AI and Blockchain Applications Beyond Healthcare

While the current solution focuses on healthcare applications, particularly dementia and Alzheimer's care, the underlying technologies of AI and blockchain can be extended to numerous other industries. The integration of decentralized platforms, smart contracts, and AI-driven analysis offers transformative potential across a wide range of sectors. This section outlines future areas where the project's infrastructure could be applied to enhance efficiency, transparency, and decision-making.

AI and Blockchain in Finance

AI-Powered Financial Analysis and Risk Management: The integration of AI for predictive analysis in finance can help institutions anticipate market trends, assess creditworthiness, and manage risks more effectively. AI algorithms can process vast datasets in real-time, helping investors and organizations optimize decisions and avoid potential financial losses. Blockchain's immutable ledger ensures that every financial transaction is transparent and traceable, reducing the risk of fraud and increasing trust among parties.

Future Implementation:

• AI can be leveraged to detect fraudulent activities in payment systems and trading platforms by analyzing anomalies in transaction patterns.

• Smart contracts on the blockchain can automate complex financial agreements, reducing the need for intermediaries and increasing transaction efficiency.

Supply Chain Optimization

Transparency and Efficiency with AI-Blockchain Integration: In the supply chain sector, AI can optimize logistics, forecast demand, and minimize disruptions through predictive analytics. Combined with blockchain technology, stakeholders can track the origin and journey of products, ensuring transparency and accountability throughout the entire supply chain process. Smart contracts can trigger automatic actions, such as order placements or payments, when pre-set conditions are met.

Future Implementation:

• AI algorithms can predict stock levels and streamline warehouse management, while blockchain ensures that all transactions between suppliers, distributors, and retailers are verifiable.

• IoT devices can feed real-time data into the system, with AI monitoring supply chain performance and blockchain storing every transaction and movement securely.

AI-Driven Personalization in Education

Personalized Learning Pathways: The education sector can benefit from AI models that analyze student performance and learning habits to create personalized education plans. AI-driven learning platforms can provide real-time recommendations for teachers and students, ensuring a more effective learning process. Blockchain can securely store academic credentials and transcripts, providing a decentralized and trustworthy system for verifying qualifications and achievements.

Future Implementation:

- AI models can assess student learning progress and suggest customized content or resources based on individual needs.
- Blockchain smart contracts can facilitate micro-certifications and verifiable credentialing, making it easier for students and professionals to demonstrate their skills and accomplishments.

Tokenization of Real World Assets (RWA) in Real Estate

Fractional Ownership and Automated Transactions: In the real estate industry, blockchain can revolutionize property transactions by enabling tokenization of real world assets like property and land. This allows for fractional ownership, making real estate investments accessible to a broader range of investors. AI can analyze market trends, predict property values, and optimize investment portfolios. Smart contracts can automate transactions, from escrow management to property transfers, reducing administrative overhead and human error.

Future Implementation:

- Tokenization on the blockchain will enable fractional ownership of properties, allowing investors to buy and sell shares in real estate with ease.
- AI-driven platforms can analyze property market data to offer investment recommendations and automatically adjust portfolios based on market dynamics.

Manufacturing and Predictive Maintenance

Enhancing Operational Efficiency: AI can predict when machinery and equipment will require maintenance, minimizing downtime and increasing operational efficiency in the manufacturing sector. IoT sensors connected to machines can feed real-time performance data to AI models that predict breakdowns before they happen. Blockchain's decentralized ledger can securely log maintenance activities, ensuring all actions are recorded and traceable.

Future Implementation:

- AI can monitor equipment performance and send automated alerts when maintenance is required, optimizing the use of resources and reducing unexpected downtime.
- Blockchain can store records of every action taken during manufacturing, from raw material sourcing to final product delivery, improving transparency and traceability.

Conclusion

The future potential of this AI and blockchain solution extends far beyond its initial healthcare applications. By leveraging AI's capabilities for predictive analysis, personalization, and optimization, combined with blockchain's transparency, security, and automation, this platform can revolutionize various sectors, including finance, supply chain, education, real estate, and manufacturing. As the platform evolves, future iterations should explore these additional use cases, maximizing the impact of AI and blockchain across industries.

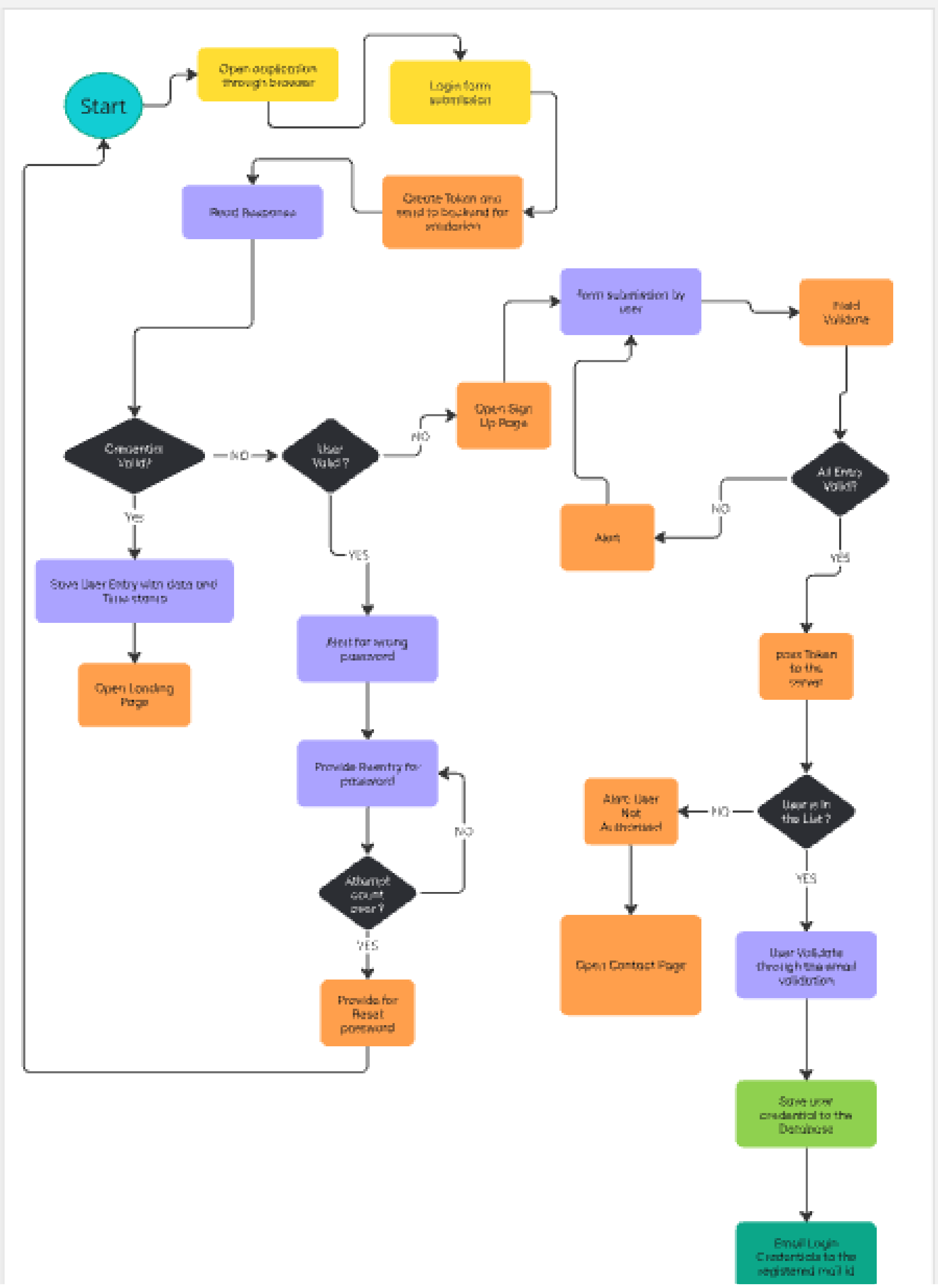


Figure 6 Functional State Diagram

API Integration

Figure 7 API integration for storage/Retrieval of METADATA

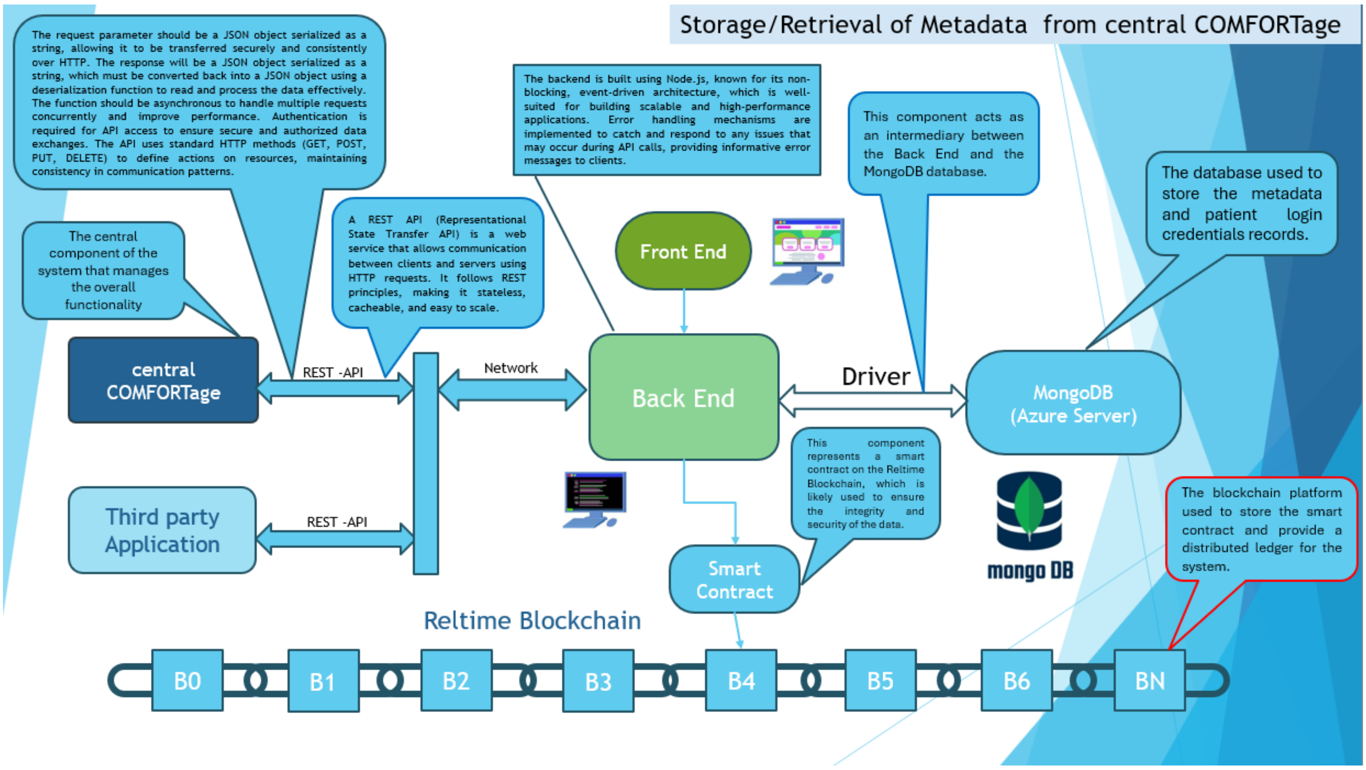


Figure 8 Block Diagram of API Integration

This image depicts the storage and retrieval of metadata from the central COMFORTage system. The key components and their interactions are as follows:

1. Central COMFORTage: The central component of the system that manages the overall functionality.

2. API: There are two types of APIs shown:

a. GET/POST API: This API is used to interact with the central COMFORTage system.

b. Third Party Application API: This API allows external applications to interact with the central COMFORTage system.

3. Internet: The connection between the various components is facilitated through the internet.

4. Front End: This component represents the user-facing interface, which could be a web application or a mobile app.

5. Back End: This component handles the business logic and processing of the system.

6. Driver: This component acts as an intermediary between the Back End and the MongoDB database.

7. MongoDB (Azure Server): The database used to store the metadata and patient records.

8. Smart Contract: This component represents a smart contract on the Reltime Blockchain, which is likely used to ensure the integrity and security of the data.

9. Reltime Blockchain: The blockchain platform used to store the smart contract and provide a distributed ledger for the system.

The image demonstrates the flow of data and metadata between the various components, with the central COMFORTage system acting as the hub that coordinates the interactions between the Front End, Back End, and the MongoDB database. The Third Party Application API allows external applications to access and integrate with the COMFORTage system, while the smart contract on the Reltime Blockchain ensures the security and transparency of the data stored within the system.

Contract Overview

The COMFORTage contract is a Solidity smart contract that implements access control and data storage functionality for a healthcare application. It uses the OpenZeppelin AccessControl and ReentrancyGuard contracts.

The contract manages two main entities:

1. **Users**: Individuals who can be approved to access the system.
2. **Patient Data**: Medical data associated with patients, stored on IPFS.

Roles

The contract defines two roles:

- **ADMIN_ROLE**: Users with this role can approve other users and grant them the PILOT_ROLE.
- **PILOT_ROLE**: Users with this role can store and retrieve patient data.

Functions

Constructor

- **Description**: Initializes the contract and grants the ADMIN_ROLE to the contract deployer.

registerUser

- **Description**: Registers a new user with the provided name.
- **Parameters**:
  - _name: The name of the new user.
- **Conditions**:
  - The user must not be already registered.
- **Emits**: UserRegistered event.

approveUser

- **Description**: Approves a registered user, granting them the PILOT_ROLE.
- **Parameters**:
  - _userAddress: The address of the user to be approved.
- **Conditions**:
  - The user must be registered.
  - The user must not be already approved.
- **Emits**: UserApproved event.

storePatientData

- **Description**: Stores patient data on IPFS and updates the contract's record of the data.
- **Parameters**:
  - _patientAddress: The address of the patient.
  - _dataType: The type of data being stored (e.g., "MRI", "Lab Results").
  - _ipfsHash: The IPFS hash of the data being stored.
- **Conditions**:
  - The caller must have the PILOT_ROLE.
  - The IPFS hash cannot be empty.
- **Emits**: DataStored event.

getPatientData

- **Description**: Retrieves the IPFS hash and timestamp of the specified patient data.
- **Parameters**:
  - _patientAddress: The address of the patient.
  - _dataType: The type of data to retrieve.
- **Conditions**:
  - The caller must have either the PILOT_ROLE or the ADMIN_ROLE.
- **Returns**:
  - ipfsHash: The IPFS hash of the stored data.
  - timestamp: The timestamp when the data was stored.

isUserApproved

- **Description**: Checks whether a user is approved (has the PILOT_ROLE).
- **Parameters**:
  - _userAddress: The address of the user to check.
- **Returns**:
  - true if the user is approved, false otherwise.

Events

- UserRegistered: Emitted when a new user is registered.
- UserApproved: Emitted when a user is approved and granted the PILOT_ROLE.
- DataStored: Emitted when patient data is stored.