Smart Heart Rate Tracking based on Kalman Filter and Time Series Analysis

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***Abstract* — Nowadays health problems like heart failure, Bradycardia (slow heart rate), Supraventricular Tachycardia (fast heart rate), and heart-related diseases are arising day by day at an extremely high rate. Due to these problems, heart rate monitoring is essential. Detection of changes in heart rate and providing preventive measures play a major role in heart disease monitoring. Frequently undergoing ECG (Electrocardiogram) tests is impractical due to their cost and the reliability factor. This project aims to develop a real-time heart rate monitoring system that not only measures the current heart rate but also predicts potential changes without the need for a doctor's physical presence. The system utilizes a fingertip MAX30102 sensor connected to a Raspberry Pi board to collect heart rate data. The collected data is then processed to provide real-time monitoring and predictive analysis. This setup offers a cost-effective and efficient alternative to traditional ECG tests, making heart rate monitoring more accessible and manageable for patients. By implementing this system, we can enhance the early detection of heart rate anomalies and provide timely preventive measures, ultimately contributing to better heart disease management and improved patient outcomes.**

Keywords — Heart rate monitoring, MAX30102, Raspberry Pi

I. INTRODUCTION

In the current era, health issues are escalating rapidly. The health status of an individual can be determined with the help of observing heart rate levels. Heart rate is a health metric associated with the cardiovascular well-being of an individual. It serves as an indicator of a person's physiological condition, encompassing factors such as activity, stress, and drowsiness. Irregular heart rates can lead to many severe health problems. So, every person needs to regularly check their heart rate, which might lead to constant visits to the doctor. In this paper, we intend to create an intelligent heart rate monitoring system that will measure the current heart rate and the predicted heart rate of the patient. The doctor can access the information on the patient's heart rate to supervise the changes in the heart rate. Moreover, in the event of an emergency, the system automatically generates alerts. These alerts are dispatched to the doctor or family members whenever any unusual activity is detected in or around the patient. The progress in innovative technology and the Internet of Things (IoT) has significantly impacted the healthcare system.

The heart rate is measured in beats per minute (bpm), every heart rate differs from one person to another. Heart rate can be divided into sections based on the age and gender of the person. Age groups less than 1 year have a normal heart rate range from 80-160 bpm, groups from 1 to 19 years have a normal heart rate range from 75–120 bpm, and adults more than 20 years have a normal heart rate range from 60 – 100 bpm[2].

The purpose of this study was to provide information about the changes in heart rate. The most common way to determine heart rate involves placing a finger on an artery to feel the pulse, counting it for roughly 30 seconds, and then doubling the result. Nevertheless, this approach lacks accuracy, so we have designed a more precise heart rate monitor system. This system uses a fingertip MAX30102 sensor to detect heart rate with the changes of oxygen level connected to a Raspberry Pi board, time series analysis to predict the heart rate, and the processed data is displayed in the application. The information provided by the app includes the heart rate per minute and the predicted heart rate of the patients. In addition, the app can frequently save your heart rate at any time. As a result, the doctor can reach the patient heart rate changes directly from the monitor screen.

This paper is organized as the following: Section 2 contains a summary of the related works in the field. Section 3 contains the proposed model of the system. Section 4 offers a description of the architecture of the system. Section 5 offers how the system is implemented. Last but not least, Section 6 shows the experimental data and the results of the system. In conclusion, this study is finalized in Section 7.

II. RELATED WORKS

A new system for real-time monitoring of heart rate is created, using a pulse sensor to detect heart rate and an adaptive filtering algorithm to improve accuracy by refining the signal. Tests demonstrate the method's effectiveness [1].

The study showcases an IoT-based system for web-monitored heart rate, oxygen levels, and temperature. This system integrates sensors like AMG8833, MAX30102, and the ESP32 microcontroller, which not only serves as a data processor but also enables Wi-Fi connectivity for seamless monitoring [2].

The IoT-based system predicts heart conditions and alerts caregivers by detecting irregular heartbeats through a fingertip sensor. It notifies nearby healthcare centers and continuously monitors patient’s blood pressure and heart rate remotely using an intelligent sensor [3].

This article suggests a way to remotely measure blood oxygen and heart rate. It covers signal conversion, remote data transmission, after analyzing the data, it can display and alarm. It emphasizes efficient remote monitoring, especially for the elderly, featuring a MAX30100 sensor-based system known for stability and wide usability as a design model for broader data monitoring [4].

The SPO2 and Heart Rate monitoring system is designed economically and delivers accuracy comparable to professional fingertip pulse oximeters. It introduces IoT for remote health monitoring Particularly useful during the COVID-19 pandemic, it allows medical practitioners to remotely monitor patients without physical proximity [5].

III. PROPOSED MODEL

The Raspberry Pi's processing capabilities allow for the implementation of algorithms to analyze and process the raw sensor readings, enabling features such as signal filtering (Kalman Filter) and data extraction. The processed heart rate data can be used to predict the future heart rate value by time series analysis. The processed heart rate data and the predicted heart rate can then be transmitted to other devices or platforms, including mobile applications or IoT environments, through communication protocols as shown in Fig. 1.

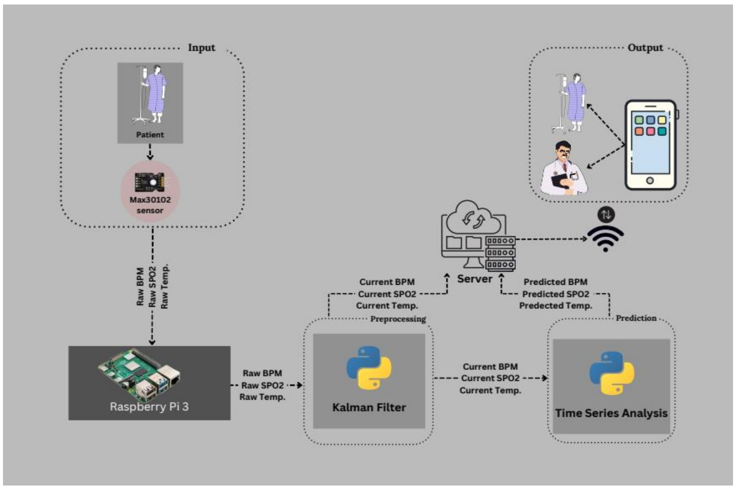

Fig. 1. Block diagram of Heart rate monitoring system

IV. SYSTEM ARCHITECTURE

The design part consists of two sections:

A. Hardware architecture

1) Raspberry Pi 3

A Raspberry Pi 3 is a tiny and budget-friendly computer that can fit in your hand. It's created for diverse projects and educational use. Despite its small size as shown in Fig. 2, it can perform various tasks similar to a regular computer. The Raspberry Pi includes ports for connecting peripherals, GPIO pins for hardware projects, and operates using microSD cards. It serves as a versatile tool suitable for both beginners and hobbyists exploring the realms of computing and electronics. can be seamlessly integrated with a heart rate sensor to form a powerful and adaptable system for heart rate monitoring. By connecting the heart rate sensor to the Raspberry Pi's GPIO pins, the device can capture real-time heart rate data.

2) MAX30102 sensor

Fig. 2 Raspberry Pi 3

The MAX30102 is a compact sensor found in devices such as fitness trackers and smartwatches. It gauges heart rate and blood oxygen levels by utilizing light. Integrating a Photoplethysmography (PPG) sensor and an ambient light sensor, this module emits light into the skin and measures variations in light absorption, allowing for the capture of the pulsatile signal associated with the heartbeat. Equipped with multiple LEDs of different wavelengths, including red and infrared, the MAX30102 ensures accurate readings by compensating for changes in ambient light conditions. Operating through the I2C interface, it facilitates seamless communication with microcontrollers and other devices. The sensor communicates with devices like Arduino and Raspberry Pi using a straightforward protocol. Due to its energy efficiency, it is well-suited for battery-powered devices, and its small size as shown in Fig. 3 makes it easy to integrate into wearables. It is frequently utilized in health-monitoring devices for continuous tracking of heart rate and oxygen levels.

Fig. 3. MAX30102

MAX30102 stands out as the best choice for heart rate tracking systems due to its exceptional combination of features. Its high accuracy in measuring heart rate and blood oxygen levels (SpO2) is crucial for medical-grade applications where precision is paramount. Additionally, the sensor's low power consumption makes it ideal for continuous monitoring without rapidly draining device batteries, ensuring prolonged usage in wearable health devices. The compact size of the MAX30102 facilitates seamless integration into wearable devices, enhancing user comfort and usability. Its digital I2C interface simplifies integration with various microcontroller platforms, making development straightforward for hobbyists, researchers, and developers. The sensor's versatility, capable of measuring both heart rate and SpO2, expands its potential applications in health monitoring. Furthermore, the MAX30102 benefits from a strong community support network, providing ample resources and support for integration and troubleshooting.

B. Software architecture

1) Kalman filter

The Kalman filter is a mathematical tool designed to improve predictions about a system's state, especially when dealing with noisy or uncertain measurements. Developed by Rudolf E. Kalman in the 1960s, it has applications in fields such as control systems and navigation. The filter operates in two main steps: first, it predicts the current state based on past data, and then it refines this prediction using new measurements. By minimizing errors in estimates, the Kalman filter is effective in scenarios involving uncertainty. It is particularly well-suited for systems with linear dynamics and Gaussian noise distribution. It helps obtain the most accurate estimate possible for a system's state. The heart rate values of the patient that were calculated by the MAX30102 sensor before and after the Kalman Filter are shown in Fig. 4. After using the Kalman Filter the data is more accurate than without using the filter.

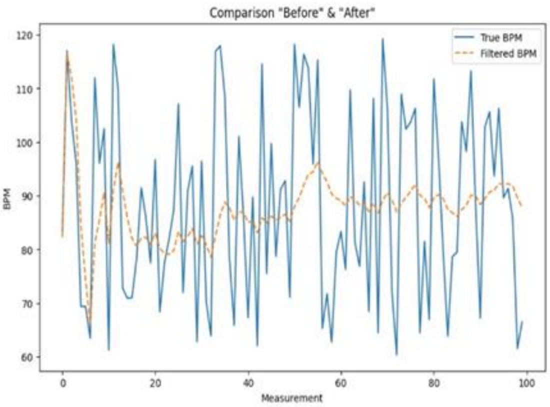

Fig. 4. Before and After applying Kalman Filter

2) Time Series analysis

Time series analysis using the Autoregressive (AR) model is a statistical technique that involves predicting future values in a time series based on past observations. In the context of a heart rate monitoring system, the AR model utilizes historical heart rate data to forecast future heart rate values. The model assumes that the current heart rate is linearly dependent on its previous values, incorporating autoregressive parameters to capture these dependencies. By training the AR model on a dataset of past heart rate measurements, it learns the patterns and trends in the data, allowing it to make predictions for subsequent time points. This predictive capability becomes valuable in anticipating fluctuations and changes in heart rate, offering a proactive approach to health monitoring. The AR model is an essential component in time series analysis for heart rate prediction, providing a tool to extract meaningful insights and support personalized healthcare interventions.

V. IMPLEMENTATION

The MAX30102 sensor is connected to Raspberry Pi as shown in Fig. 5. Sensor readings use I2C communication, namely communication between two ICs using the SDA (serial data) and SCL (serial clock) pins. The voltage used by this sensor is 3.3 volts. The ground in the sensor is connected to the ground in the Raspberry Pi. The SDA pin of the sensor is connected to GPIO 2 Serial Data (I2C) pin in the Raspberry Pi and the SCL pin of the sensor is connected to GPIO 3 Serial Clock (I2C) pin in the Raspberry Pi. The current use of SCL is to control the transmission of sensor data from the sensor via SDA to the microcontroller. The function of this sensor consists of two LEDs, a red LED, and an IR (infrared) photodetector. Photodetectors are located on either side of the probe to capture the light that is scattered and then detected after passing through body tissues. Infrared light is absorbed by hemoglobin, which has a high oxygen content, and hemoglobin, which does not contain oxygen, absorbs red light.

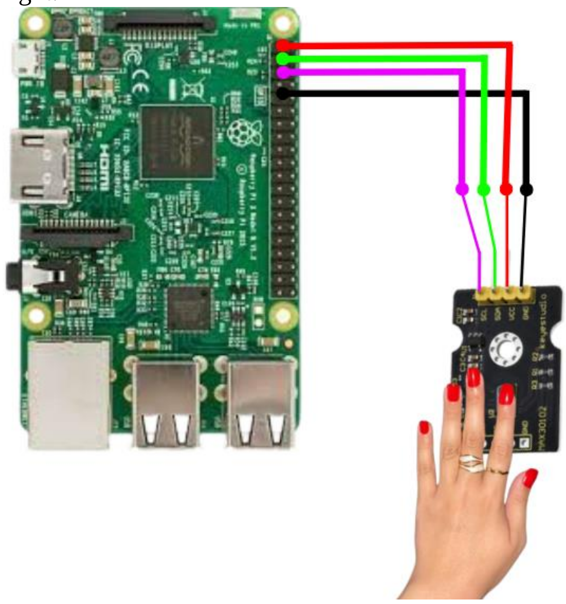

Fig. 5. Fingertip on MAX30102 sensor

When the patient puts the fingertip on the MAX30102 as shown in Fig. 5, the sensor emits light through the skin. By analyzing how blood absorbs this light, the sensor can distinguish between oxygenated and deoxygenated hemoglobin. It then creates a PPG, representing changes in blood volume over time. Using the PPG waveform, the sensor calculates the patient's heart rate and blood oxygen saturation (SpO2). This information is sent to the Raspberry Pi, the next step involves passing this data through a Kalman filter to help enhance the precision of heart rate and oxygen saturation readings by reducing signal noise and errors that may arise from various sources. This filtering process is valuable in obtaining more reliable and stable physiological measurements for further analysis and interpretation.

Once the MAX30102 sensor collects the data, the Raspberry Pi retrieves the raw data, which typically includes measurements such as heart rate, oxygen saturation, and pulse oximetry. This raw data may contain noise or inconsistencies that need to be filtered out for accuracy. To enhance the accuracy of the measurements, the Raspberry Pi applies a Kalman filter, a widely used algorithm for state estimation. The Kalman filter helps in reducing noise and improving the precision of the sensor data by predicting the most accurate value based on the sensor's previous measurements and the system dynamics. After applying the Kalman filter, the Raspberry Pi further calibrates the data before formatting it into a suitable structure for transmission to Google Firebase. This involves converting the data into a JSON (JavaScript Object

Notation) format, which is widely used for data interchange. Additionally, the Raspberry Pi prepares the data for transmission by encrypting it for security and adding metadata such as timestamps for tracking and analysis purposes. This meticulous process ensures that the data collected by the sensor is accurately processed and securely transmitted to Google Firebase for real-time monitoring and analysis.

Using the WebSocket protocol, the Raspberry Pi establishes a secure and persistent connection with the Google Firebase Realtime Database. Once this connection is established, the processed patient data is transmitted in real-time over the WebSocket connection. Unlike traditional HTTP requests, which require establishing a new connection for each data transmission, WebSocket maintain a continuous connection between the Raspberry Pi and Google Firebase, ensuring low latency and efficient data transmission. This real-time transmission allows healthcare professionals to access and analyze patient data as soon as it is collected by the sensor, enabling timely interventions if necessary. The data is securely stored in the Firebase database, where it can be accessed and analyzed in real-time using a web or mobile application. Real-time monitoring of patient vital signs becomes possible, providing healthcare professionals with valuable insights and enabling them to make informed decisions to improve patient outcomes. This real-time communication between the Raspberry Pi and Google Firebase via WebSocket ensures that healthcare professionals always have access to the latest patient data, facilitating better patient care and monitoring.

After the data is filtered and initializing the Firebase Admin and Admin-SDK to access heart rate data stored in Firestore the Autoregressive retrieves heart rate and timestamp data for each user from the Firestore database. (AR) model the uses past heart rate values to predict the future one. After retrieving the data, it creates a Data Frame to organize the heart rate and timestamp data. It performs a quick check for autocorrelation and plots lag plots and autocorrelation plots to visualize the temporal dependencies in the heart rate data. They assign different weights to each past heart rate, capturing patterns in the data. Training involves teaching the AR model by adjusting its internal settings. It learns from historical heart rate data to make accurate predictions by recognizing patterns. To make sure the predictions are on point, we use metrics like Mean Squared Error as shown in Figure 14 the predicted value and 98% accuracy. This helps us understand how well the AR model is doing and guides us in making improvements. Once trained, the AR model can predict future heart rates based on what it learned from the past.

After the AR model accurately predicts your heart rate, the next step involves delivering this valuable information to your mobile app through firebase. This real-time connection ensures that your health insights are instantly accessible on your smartphone. As the AR model forecasts your heart rate, Firebase transmits the predictions to your mobile app, allowing you to receive timely notifications and stay updated on your cardiovascular health trends. This integration empowers you to make informed decisions, whether adjusting your lifestyle or seeking professional advice. The user-friendly interface of the mobile app as shown in Figure 15 provides visualizations and historical data, offering a comprehensive view of your well-being. With a focus on privacy and security, Firebase ensures that your health data is transmitted safely. This dynamic fusion of predictive health modeling and mobile technology creates a future where health insights seamlessly integrate into your daily life, providing a convenient and personalized approach to proactive healthcare.

Fig. 6. Mobile application

VI. RESULTS

The results of 5 different patients in different activity statuses with the information of the patients are shown in the following Table 1. Sensor data after being filtered by the Kalman filter and future predicted heart rate every two hours are also shown in Table 1. Patient 1, Patient 3, and Patient 4 show normal heart rates while Patient 2 and Patient 5 show abnormal heart rates.

Patients	Activity	Gender	Age	Heart Rate (bpm)	SpO2 (%)	Predicted Heart Rate (bpm)
Patient 1	Walk	Female	25	73	95	80
	Run			93	97	94
	Sit			71	98	76
Patient 2	Walk	Male	30	44	87	45
	Run			46	85	48
	Sit			41	90	41
Patient 3	Walk	Female	20	75	96	79
	Run			84	95	80
	Sit			81	97	78
Patient 4	Walk	Male	50	82	97	84
	Run			83	98	85
	Sit			78	97	75
Patient 5	Walk	Male	60	137	87	136
	Run			142	85	139
	Sit			128	91	131

Table 1. Sensor data after being filtered and the predicted value

The patient can access the history of the heart rate and SPO2 from the application, see the next predicted value of heart rate and check if the heart rate range is normal or abnormal through the application. If the patient's heart rate is abnormal then the application sends a notification to the patient and can contact any emergency doctor or any family member. The patient's doctor can reach the heart rate and oxygen saturation changes through the monitor screen.

VII. CONCLUSION

This paper presents a heart rate and oxygen saturation monitoring system using Raspberry Pi, MAX30102 sensor, Kalman filter, and time series analysis which is a powerful and effective solution for real-time health tracking and predicting heart rate. The Raspberry Pi handles the data processing, the Kalman filter improves measurement accuracy, and time series analysis predicts future heart rates based on historical data. Firebase ensures smooth communication between devices for remote monitoring. This system helps to monitor heart rate and oxygen level of individuals who are unable to make regular visits to hospitals, simplifying primary health checkups. Storing patients' medical history on the server facilitates follow ups. By leveraging information technology, the system eliminates human errors, leading to improved performance.

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A virtual pet for children with autism spectrum disorders (ASD)

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***Abstract*— In Egypt, about 33.6% of children with developmental disabilities have Autism Spectrum Disorder (ASD), social challenges are particularly acute for those with Asperger syndrome, often leading to marginalization and limited opportunities. This project proposes an innovative solution: an Android application featuring an interactive virtual pet companion powered by augmented reality (AR). Developed with the Unity game engine and MediaPipe for pose estimation, the app aims to provide a safe and engaging platform for children with Asperger syndrome to practice social interaction, develop emotional learning skills, and combat social isolation. This project targets children aged 5-12, seeking to improve their social skills, emotional regulation, and engagement with their surroundings through playful interaction with the virtual pet. By addressing the unique needs of children with Asperger syndrome in the Egyptian context, this project has the potential to foster their social integration and well-being, paving the way for a more inclusive future. Evaluation reveals promising results (software-wise), with a 92% effectiveness rate in guiding users toward goals, 93% efficiency in resource utilization, and manageable technical performance.**

Keywords—Augmented Reality (AR), Autism Spectrum Disorder (ASD), Asperger syndrome, Extend Reality (XR), MediaPipe, Unity game engine.

I. INTRODUCTION

According to the World Health Organization (WHO) **Autism spectrum disorders (ASD)** are neurodevelopmental disorders, meaning they are caused by abnormalities in the way the brain develops and works [1]. Early diagnosis of ASD is crucial for early intervention and better prognosis. However, it is often delayed until preschool or school age. [2]. Asperger's syndrome is an ASD subtype that this project focuses on in its first phase. Individuals with Asperger's syndrome experience difficulties with social communication and interactions, including verbal and non-verbal communication, and may have peculiar behaviors, such as stereotypies and limited interests [3].

In Egypt, the prevalence of ASD among children with developmental disorders in Egypt was documented to be 33.6% most of the children diagnosed with autism came from families of low socioeconomic status [4]. Today, access is limited by geography, socioeconomics, or global health concerns such as the COVID-19 pandemic, and having mobile healthcare solutions that work beyond traditional clinical settings can ensure access to quality care [5] and studies show that games help improve the social and emotional skills of people with autism [6]. Existing solutions for ASD intervention often rely on clinical settings or expensive equipment, limiting accessibility [3]. This project focuses on mobile healthcare solutions, leveraging the high prevalence of mobile phones to deliver interventions directly to users. Additionally, the project incorporates gamified training programs, a well-established technique for improving social and emotional skills in a fun and engaging way [6] [7]. By combining mobile accessibility with gamified training, this project offers a novel and potentially transformative approach to ASD intervention.

It is worth noting that almost everyone has access to mobile phones, with Android phones being the most widely used. This Android app, developed with Unity, a popular game engine for augmented reality (AR), uses ARCore to bridge the physical and virtual realms. By tracking body movements through MediaPipe and translating them into data points, the app lets users with Asperger's syndrome interact with virtual objects in an AR environment, promoting independence and social inclusion globally.

This paper is organized as follows: section 2 contains a summary of the lecture review. Section 3 contains how the application is implemented, section 5 is a methodology, and finally, section 6 shows the evaluation of the application. In conclusion, this study is finalized in section 7

II. LITERATURE REVIEW

In recent years, virtual pets have emerged as a potential therapeutic tool for children with ASD. These interactive companions offer several advantages, including providing companionship, promoting social-emotional learning, and reducing anxiety and stress. This literature review critically examines the existing research on virtual pets for children with ASD, exploring their potential benefits, limitations, and underlying mechanisms of action.

A. Positive Impact

Studies have shown that virtual pets can positively impact children with ASD. Below are the key findings:

1) ***Improved social engagement and communication***: A study published in the Journal of Autism and Developmental Disorders in 2019 revealed that children with ASD significantly improved their social engagement and communication skills after interacting with a virtual pet for 12 weeks. The study used Paro, a plush robotic seal that responds to touch, voice, and gaze through sensors and actuators. The children who interacted with Paro exhibited increased initiations of interaction and turn-taking behavior. Specifically, they showed increased

initiations of interaction, turn-taking behavior, and joint attention [8].

2) ***Reduced anxiety and stress***: A 2020 study published in the International Journal of Play reported that children with ASD used a virtual pet app on tablets. The app featured an animated dog that responded to the child's touch and voice, offering companionship, and promoting relaxation. companion showed reductions in anxiety and stress levels, as measured by physiological indicators like heart rate. Additionally, they reported feeling calmer and more comfortable in social situations [9].

3) ***Enhanced empathy and compassion***: A 2022 study published in the International Journal of Human-Computer Studies investigated the use of a virtual pet application on empathy development in children with ASD using a smartphone app featuring a virtual pet dog alongside interactive stories and games focused on emotions. The results showed that children who interacted with the app demonstrated increased prosocial behavior and empathy towards others, indicating a potential transfer of learned empathy skills to real-world settings [10].

B. Beyond the Benefits

While these findings highlight the potential of virtual pets, it is crucial to acknowledge their limitations. Studies have yielded mixed results, and concerns regarding social isolation and limited generalizability to real-world interactions remain. Individual differences in learning styles and symptoms also play a role in effectiveness. Therefore, careful monitoring and integration with other therapeutic interventions are essential for successful implementation.

Despite these challenges, virtual pet interventions offer a unique, interactive, and personalized approach to traditional ASD therapy. They promote empathy, positive behavior, and emotional growth, and cater to individual needs. Further research is needed to explore different virtual pet designs, functionalities, and applications, refining their efficacy and generalizability.

III. IMPLEMENTATION

This section outlines the implementation process of a virtual pet app that utilizes Unity, ARCore, and MediaPipe for body detection and object manipulation. However, this project does not require any hardware parts.

Augmented Reality (AR) technology involves the integration of virtual objects and other digital content including images with physical or real-world content [11]. AR enables us to overlay virtual objects onto real-world surfaces with precision, creating an illusion that they exist in the same space. This enhances the realism and interactivity of the AR experience significantly. It is widely known that the Unity and Unreal game engines are the most powerful tools available for designing AR environments. Compatibility with available computer resources, including RAM, memory, and graphics card, led to the selection of the Unity game engine for this project. Below is a description of each technology and its respective role in the project.

A. Unity game engine

Unity game engine that is widely used for creating and operating interactive, real-time 3D content. The platform offers a range of software solutions to develop, run, and monetize interactive, real-time 2D and 3D content for various devices such as mobile phones, tablets, PCs, consoles, and augmented and virtual reality devices. ARCore is an AR platform API specifically designed for Android apps and serves as a foundational technology within this project. The purpose of using ARCore is to project a virtual pet and your body pose onto the real-world environment. For this project, I utilized Unity version 2021.3.17f1 along with the XR-Plugin version 4.3.

B. Unity UI Toolkit

Unity UI Toolkit is a framework designed for building user interfaces (UI) in Unity, offering a more flexible, modern, and performant approach than the legacy Unity UI system. Key features include the UI System, which uses a visual hierarchy of elements, a declarative syntax (UXML) for layout and visual structure, and a style sheet language (USS) for styling elements. This toolkit has modern architecture, flexibility, performance optimization, and ease of use.

C. Unity Machine Learning Agents Toolkit

ML-Agents is an open-source kit that allows games and simulations to serve as environments for training intelligent agents. The toolkit supports popular RL algorithms like Proximal Policy Optimization and Soft Actor-Critic. Using them, a virtual pet can be developed that is tailored to each child's needs based on the severity of the disorder.

D. MediaPipe

MediaPipe Pose estimation is a vital tool for capturing real-world object data. By keeping track of the key points and dimensions of real-world objects, MediaPipe provides the necessary information for virtual material placement and manipulation. This ensures a natural and intuitive interaction with the AR scene.

E. Programming languages

For this project, C# Script was utilized to interact with Unity on a Visual Studio IDE. Python 3.11.4 was also used to implement and control the MediaPipe pose estimation framework and transmit points back to Unity. These languages were chosen for their dependability and widespread use.

IV. METHODOLOGY

This section presents the project in three stages. The first stage involved designing a prototype, which was not evaluated on children. The prototype includes activities suitable for children with Asperger syndrome, such as playing with cubes with a virtual pet, and simple exercises like raising hands. It also features emojis and words that express feelings.

The second phase incorporates educational games for the Arabic language. The third phase aims to expand the application to cover a wider range of ASD.

The application boasts unique machine-learning capabilities that allow the virtual pet to recognize each child's needs and adjust its behavior accordingly. As the child spends more time with the application, the virtual pet's experience will grow, making it more effective for individual cases of autism spectrum disorders. These features will be explained in more detail in the following sections.

A. System Architecture

The application's architecture comprises three core modules. representing body pose. Secondly, Virtual Pet Behavior leverages the extracted body pose data to dynamically control the virtual pet's movements, animations, and responses based on the child's actions. Lastly, Object Manipulation maps specific body gestures to trigger interactions with AR objects, enabling children to manipulate them through their movements. The application ran smoothly on all tested devices with minimal lag or technical issues. The AR integration provided a stable and immersive experience for users.

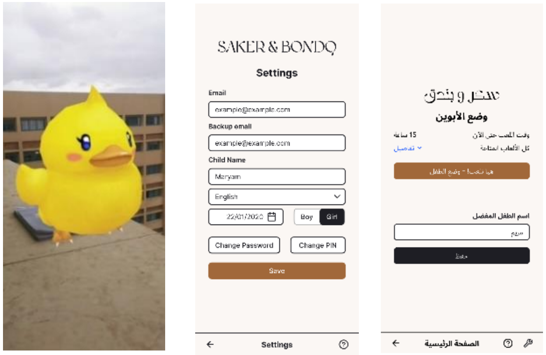

Fig. 1. Random screenshots of the application interface during the initial development stages.

B. Plugin Mediapipe into Unity

This section dives into the technical heart of the project, unveiling how various technologies seamlessly cooperate to manipulate materials in real time, responding to both hand gestures and the surrounding environment.

There are two key steps:

1) ***Capture***: A camera captures real-world video. MediaPipe Pose within Unity (using Python bindings) detects objects and body positions. User input directly controls virtual materials.

2) ***Hand Tracking***: MediaPipe's hand skeleton model tracks user hand movements. Preprocessing cleanses data for accurate pose detection. Key points, angles, and orientation guide AR interactions. The virtual pet responds to specific hand movements.

Fig. 2. MediaPipe landmarks for body

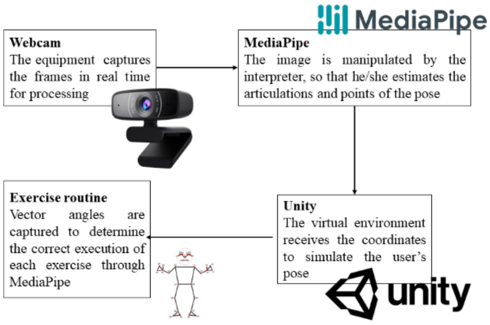

Fig. 3. Block diagram of application core

C. User Interface

While effectiveness dominates design in most Android apps, especially prototypes, a different approach is crucial for apps aiming to serve unique user groups like children with Asperger's syndrome. Their strong visual-driven nature necessitates a carefully crafted interface rich in colors and engaging graphics. Furthermore, supporting the Arabic language necessitates additional UI considerations.

This section delves into the distinguishing features that set this application apart from regular games, highlighting how its interface caters to the specific needs of its target audience.

An outline was created for the UserFlow diagram, and the login process was designed in Figure 1. Parents must log in to their account, followed by their child's pet account for a safer and monitored environment. Figma was used for designing wireframes and prototypes using happy colors like yellow and blue preferred by children with Asperger's, [3] along with big fonts and shapes to make the app more user-friendly.

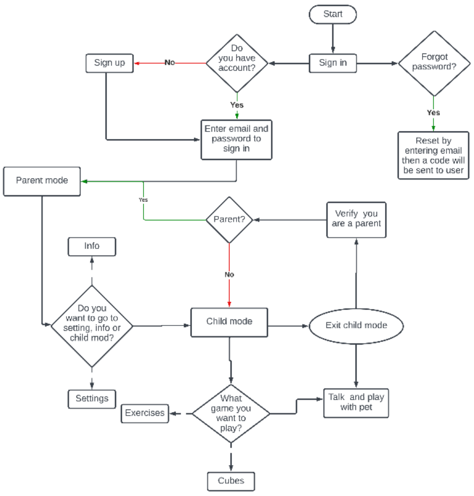

Fig. 4. UserFlow Diagram

D. Interaction Design

This section focuses on the crucial aspect of designing interactive experiences for augmented reality applications that feature virtual pets for children with ASD.

To ensure a positive experience, it is important to create virtual pets that are both engaging and relatable. The game should have simple and intuitive gestures that allow children to easily access different abilities. Giving children the option to choose a name for their virtual pet and even selecting a name that their pet prefers to call them can make them feel more connected to the game which achieves the persona concept.

To keep children motivated and engaged, the game has plenty of activities and challenges such as puzzles, cubes, and physical exercise. Additionally, children should receive rewards and achievements to celebrate their progress and reinforce desired behaviors.

E. Virtual Pet and Artfiial intallgent

Unity itself offers built-in features like navigation meshes for pathfinding, animation blending for smooth character movement, and physics simulations that can benefit from machine-learning techniques for enhanced realism and interactivity. This suggests that unit ML tools could at least theoretically be used to create virtual pets specifically designed for each child, helping to achieve persona concepts.

Unity ML-Agents Toolkit provides a wide range of services, but this project focuses on customizing (persona concept) the virtual pet. The pet must learn whether the child is progressing or not. The virtual pet goes through a large number of convolutional networks that make it automatically create imaginary scenarios and train on them based on what it receives, which means that The longer the application is used, the more the virtual pet learns.

V. EVALUATION

Under the ISO 9241-11:2018 standard, this section explores usability metrics aligned with the core principles of effectiveness, efficiency, and satisfaction. While the app hasn't been tested with autistic children due to certain limitations, local doctors have expressed positive feedback, suggesting it could be a promising tool for this population.

A. ***Effectiveness or (Accuracy)***: The task Completion Rate is used to measure and evaluate a child's interaction with a virtual pet, object manipulation, or specific game objectives. It determines the accuracy and completeness with which users achieve special goals. Effectiveness, a percentage of successful users, is calculated by dividing successful completions by total users. Then, overall integral product effectiveness E will be calculated as shown in equation .1.

$$E = \frac{number\ of\ task\ completed\ successfully\ for\ all\ users}{total\ number\ of\ tasks} \times 100 \qquad (1)$$

Designed ten different tasks with varying levels of difficulty to assess the effectiveness of the application. Fifty participants completed these tasks. The results indicate that the overall effectiveness of the prototype is 92%, which is considered acceptable. The application helped users select the appropriate value for their use and choose the appropriate scenario for each user from a variety of proposed scenarios.

B. ***Efficiency***: defined as the number of resources used by the user to achieve their goals accurately and completely, according to the application. Regarding software products, time is the most valuable resource to measure efficiency in terms of task time. The overall efficiency of a product is calculated as the percentage of time taken by participants to complete a task compared to the total time taken by all participants, whether the task was completed successfully or unsuccessfully as shown in equation .2.

$$F = \frac{total\ time\ of\ task\ completed\ successfully\ for\ all\ users}{total\ time\ of\ tasks} \times 100 \qquad (2)$$

The results show that the overall efficiency of the prototype is 93% which is a high value.

C. ***CPU and memory usage***: it refers to the resources your computer utilizes when running applications and processes. CPU usage is the percentage of processing power the computer utilizes, while memory usage represents the amount of RAM used by applications and processes. It is essential to monitor these resources to ensure optimal performance. The prototype's CPU usage is 21.5%, falling within the range of normal activity. Memory usage is 56.5%, also aligning with typical usage expectations [12].

TABLE I. RESULT SUMMARY

	Effectiveness	***Efficiency***	***CPU usage***	***Memory usage***
Result	**92%**	**93%**	**21.5%**	**56.5%**
Indicating	Acceptable	High	Normal	Normal

VI. CONCLUSION

This project presents a novel virtual pet application built with augmented reality and MediaPipe for body detection, aimed at engaging children with ASD and potentially improving their emotional and behavioral development. The prototype successfully captured children's attention and achieved an impressive 93% efficiency and 92% accuracy in its initial model. While these results are promising, further refinement is needed. Future iterations should prioritize enhancing the accuracy of individual virtual pet interactions, particularly in body and behavior detection. Additionally, conducting long-term studies will be crucial in evaluating the sustained effectiveness of such applications on children with ASD.

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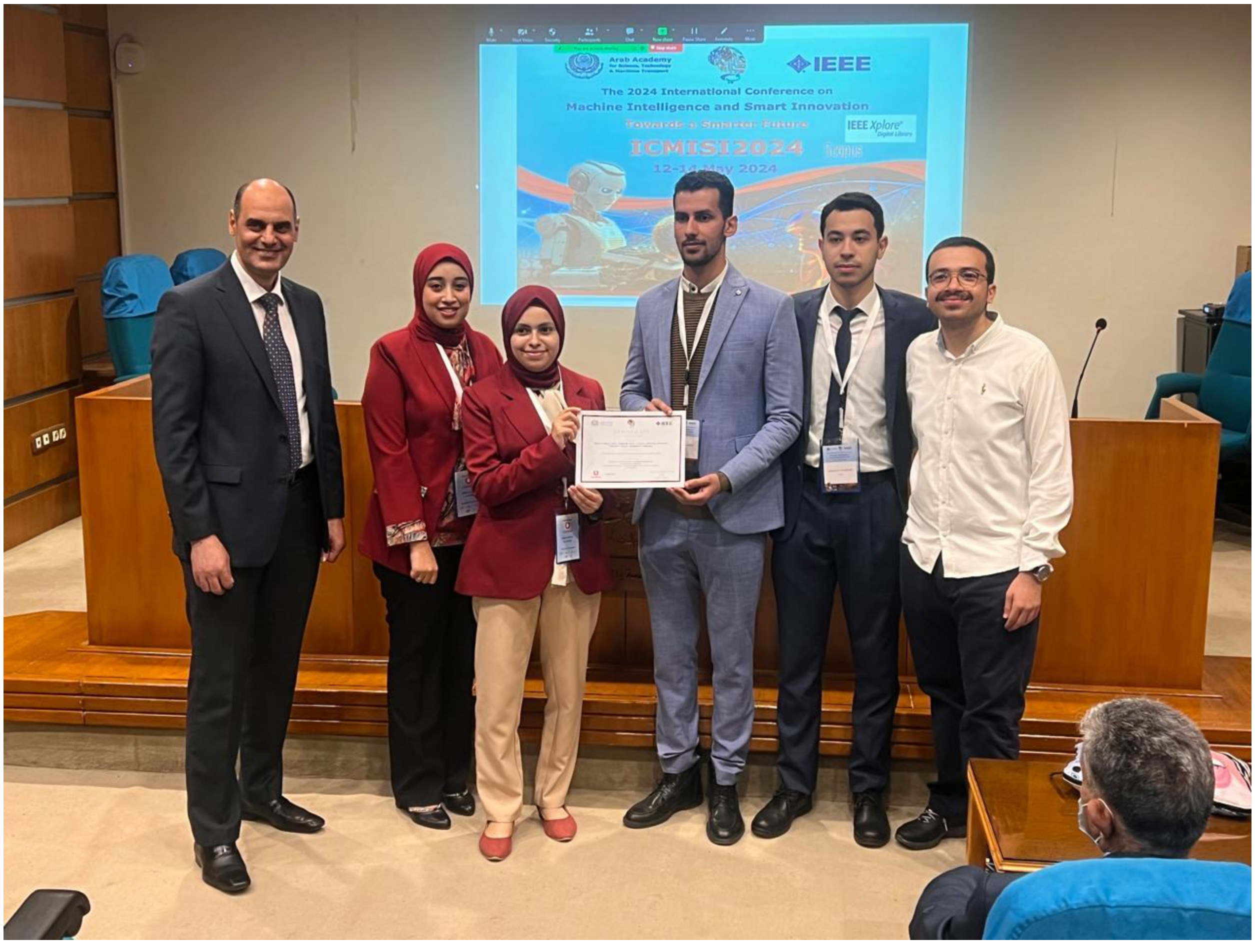
مشروع مجتمعى

كما تشارك المؤسسات الإنتاجية في الإشراف على مشاريع التخرج بحيث يكون البحث يخدم الهيئة او المؤسسة المشتركة في مشروع التخرج، ومثال على ذلك مشروع تخرج (Graduation Project) لطلاب الفرقة الخامسة ببرنامج هندسة الحاسب بعنوان A Virtual Pet for Children with Autism Spectrum Disorders (ASD))تحت إشراف د. عبد الغفار الشناوى والذى فاز بالمركز الثانى فى مسابقه) intra Africa 2063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قاعة المؤتمرات

نظم قسم هندسة الحاسب بكلية الهندسة جامعة فاروس بالإسكندرية وتحت رعاية إدارة الأنشطة الطلابية بالكلية وبالتعاون مع الفرع الطلابي (ACM) محاضرة تحت عنوان:
"The Process of Making a modern product"
ألقاها ضيف القسم صاحب الخبرة في مجال الأنظمة المدمجة المهندس/ جورج لويس – مهندس الالكترونيات والأنظمة المدمجة والذي عمل في اكثر من شركة عالمية في أوروبا، وذلك يوم الثلاثاء الموافق 2022/10/25 بمدرج (E112) بكلية الهندسة.

استهل المحاضرة كلمة إفتتاحية ألقاها الأستاذ الدكتور/ مجدي عبد العظيم - المشرف الأكاديمي لقسم هندسة الحاسب بكلية الهندسة جامعة فاروس بالإسكندرية ود.هبة رأفت المدرس بقسم هندسة الحاسب ، رحب من خلالها بضيف القسم المهندس/ جورج لويس، تلي ذلك إلقاء الضوء على مجال الأنظمة المدمجة وهو اتجاه عالمي خلال الفترة الحالية، حيث من المقرر إستحداث ظهور وظائف جديدة يحتاج إليها سوق العمل لم تكن موجودة من قبل، في حين إختفاء وظائف أخرى حالية ستتم إستبدالها بالأنظمة المدمجة والانسان الالي في الشركات والمصانع وخطوط الإنتاج بمختلف المجالات الهندسية والصناعية.

كما ناقش المهندس جورج خلال المحاضرة عدة نقاط والتي كان من أهمها التركيز على أهمية الأنظمة المدمجة والتطور الهائل الذي حدث خلال العقدين الماضيين في هذا المجال وقدم امثلة عملية حالية في مجالات الزراعة والإنتاج الحيواني يتم فيها استخدام الأنظمة المدمجة والتي حلت بديلا للأيدي العاملة في هذه المجالات.

إختتمت فاعليات المحاضرة بمناقشة تطلعات الطلاب وإهتماماتهم في هذا المجال وكيفية تأهيل الطالب لنفسه بعد التخرج ليكون مرشح منافس في سوق العمل استعداداً للدخول في مجال الأنظمة المدمجة والالكترونيات


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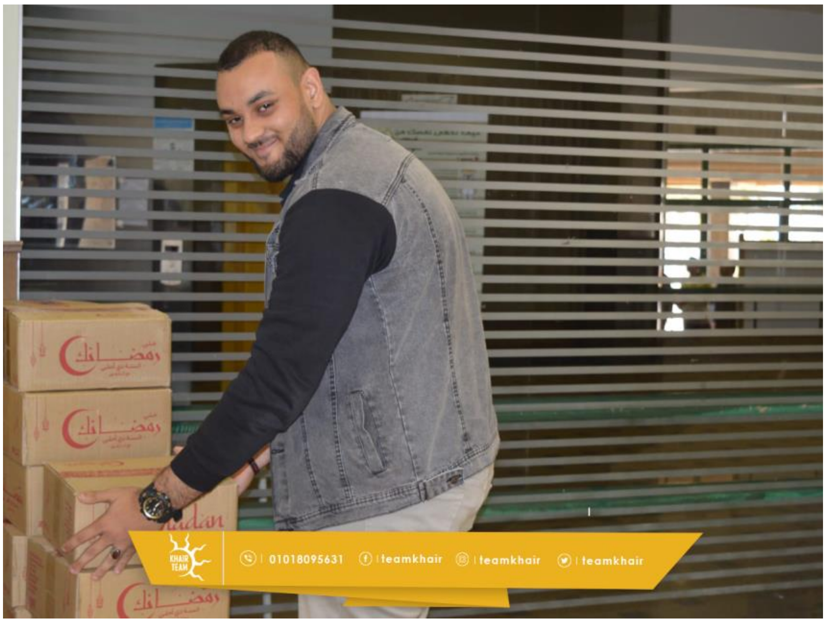
التاريخ الخاص بالخبر / النشاط **"تاريخ إقامة الحدث أو النشاط"**	**اليوم**: الثلاثاء — **التاريخ**: 2022-3-29
مكان إقامة الحدث / النشاط	كلية الهندسة
أسماء السادة الحضور **"الأشخاص المشاركين بالحدث / النشاط"**	**الإسم** / **المسمى الوظيفي**: د.هبة رفت — مدرس بقسم هندسة الحاسب م/ محمود عبد العاطي — مدرس مساعد بقسم هندسة البتروكيماويات م/ عمرو ممدوح — مدرس مساعد بقسم الهندسة الميكانيكية م/ كريم نبات — مدرس مساعد بقسم هندسة البتروكيماويات
الهدف من هذا الحدث	
محتوى الخبر / النشاط "التفاصيل الخاصة بالحدث / النشاط" برجاء توفير معلومات كافية عن الحدث أو النشاط	في إطار حرص كلية الهندسة على الإلتزام بمسئوليتها الإجتماعية نحو المجتمع وغرس القيم الإنسانية فى نفوس طلابها مما يساعد فى بناء شخصيتهم ، نظمت كلية الهندسة سوق خيري يوم الثلاثاء الموافق 2022/3/29 تحت إشراف إدارة الأنشطة الطلابية و بالتعاون مع اسرة خير تيم. بدأت فعاليات السوق فى تمام الساعة 12.30 ظهرا داخل احدى القاعات بمبنى كلية الهندسة حيث تم توفير الكثير من السلع الاساسية في صورة حقيبة رمضانية يتم بيعها بسعر رمزي كنوع من الدعم بمناسبة حلول شهر رمضان الكريم حيث ساد جو من الالفة و الترابط .
كلمات بحث / دالة "Keyword"	**برجاء وضع بعض الكلمات الدالة أو كلمات البحث للنص بحيث تكون أهم الكلمات داخل النص مع العلم أنه ستساهم في مساعدة القارئ على إيجاد النص عند إستخدام أحد تلك الكلمات على محرك البحث "جوجل"** PUA — كلية الهندسة — سوق خيري — خير تيم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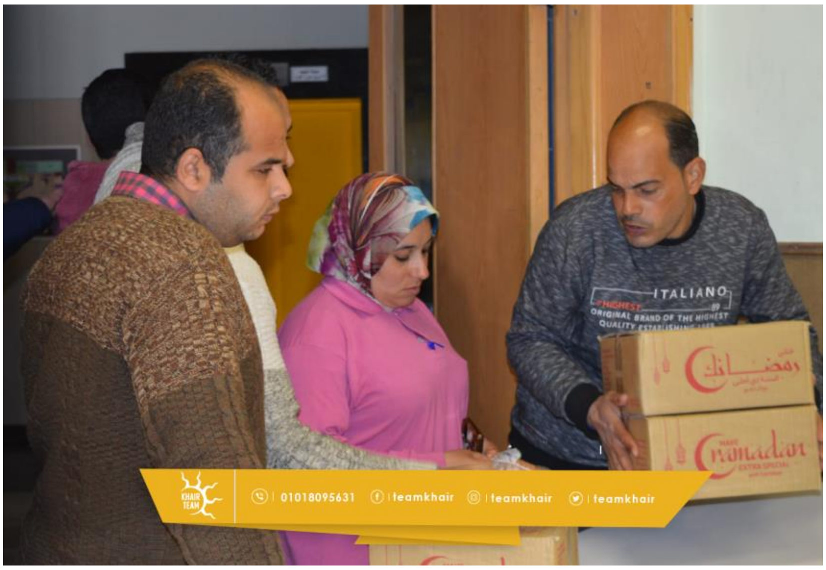
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Smart Heart Rate Tracking based on Kalman Filter and Time Series Analysis

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***Abstract* — Nowadays health problems like heart failure, Bradycardia (slow heart rate), Supraventricular Tachycardia (fast heart rate), and heart-related diseases are arising day by day at an extremely high rate. Due to these problems, heart rate monitoring is essential. Detection of changes in heart rate and providing preventive measures play a major role in heart disease monitoring. Frequently undergoing ECG (Electrocardiogram) tests is impractical due to their cost and the reliability factor. This project aims to develop a real-time heart rate monitoring system that not only measures the current heart rate but also predicts potential changes without the need for a doctor's physical presence. The system utilizes a fingertip MAX30102 sensor connected to a Raspberry Pi board to collect heart rate data. The collected data is then processed to provide real-time monitoring and predictive analysis. This setup offers a cost-effective and efficient alternative to traditional ECG tests, making heart rate monitoring more accessible and manageable for patients. By implementing this system, we can enhance the early detection of heart rate anomalies and provide timely preventive measures, ultimately contributing to better heart disease management and improved patient outcomes.**

Keywords — Heart rate monitoring, MAX30102, Raspberry Pi

I. INTRODUCTION

In the current era, health issues are escalating rapidly. The health status of an individual can be determined with the help of observing heart rate levels. Heart rate is a health metric associated with the cardiovascular well-being of an individual. It serves as an indicator of a person's physiological condition, encompassing factors such as activity, stress, and drowsiness. Irregular heart rates can lead to many severe health problems. So, every person needs to regularly check their heart rate, which might lead to constant visits to the doctor. In this paper, we intend to create an intelligent heart rate monitoring system that will measure the current heart rate and the predicted heart rate of the patient. The doctor can access the information on the patient's heart rate to supervise the changes in the heart rate. Moreover, in the event of an emergency, the system automatically generates alerts. These alerts are dispatched to the doctor or family members whenever any unusual activity is detected in or around the patient. The progress in innovative technology and the Internet of Things (IoT) has significantly impacted the healthcare system.

The heart rate is measured in beats per minute (bpm), every heart rate differs from one person to another. Heart rate can be divided into sections based on the age and gender of the person. Age groups less than 1 year have a normal heart rate range from 80-160 bpm, groups from 1 to 19 years have a normal heart rate range from 75–120 bpm, and adults more than 20 years have a normal heart rate range from 60 – 100 bpm[2].

The purpose of this study was to provide information about the changes in heart rate. The most common way to determine heart rate involves placing a finger on an artery to feel the pulse, counting it for roughly 30 seconds, and then doubling the result. Nevertheless, this approach lacks accuracy, so we have designed a more precise heart rate monitor system. This system uses a fingertip MAX30102 sensor to detect heart rate with the changes of oxygen level connected to a Raspberry Pi board, time series analysis to predict the heart rate, and the processed data is displayed in the application. The information provided by the app includes the heart rate per minute and the predicted heart rate of the patients. In addition, the app can frequently save your heart rate at any time. As a result, the doctor can reach the patient heart rate changes directly from the monitor screen.

This paper is organized as the following: Section 2 contains a summary of the related works in the field. Section 3 contains the proposed model of the system. Section 4 offers a description of the architecture of the system. Section 5 offers how the system is implemented. Last but not least, Section 6 shows the experimental data and the results of the system. In conclusion, this study is finalized in Section 7.

II. RELATED WORKS

A new system for real-time monitoring of heart rate is created, using a pulse sensor to detect heart rate and an adaptive filtering algorithm to improve accuracy by refining the signal. Tests demonstrate the method's effectiveness [1].

The study showcases an IoT-based system for web-monitored heart rate, oxygen levels, and temperature. This system integrates sensors like AMG8833, MAX30102, and the ESP32 microcontroller, which not only serves as a data processor but also enables Wi-Fi connectivity for seamless monitoring [2].

The IoT-based system predicts heart conditions and alerts caregivers by detecting irregular heartbeats through a fingertip sensor. It notifies nearby healthcare centers and continuously monitors patient’s blood pressure and heart rate remotely using an intelligent sensor [3].

This article suggests a way to remotely measure blood oxygen and heart rate. It covers signal conversion, remote data transmission, after analyzing the data, it can display and alarm. It emphasizes efficient remote monitoring, especially for the elderly, featuring a MAX30100 sensor-based system known for stability and wide usability as a design model for broader data monitoring [4].

The SPO2 and Heart Rate monitoring system is designed economically and delivers accuracy comparable to professional fingertip pulse oximeters. It introduces IoT for remote health monitoring Particularly useful during the COVID-19 pandemic, it allows medical practitioners to remotely monitor patients without physical proximity [5].

III. PROPOSED MODEL

The Raspberry Pi's processing capabilities allow for the implementation of algorithms to analyze and process the raw sensor readings, enabling features such as signal filtering (Kalman Filter) and data extraction. The processed heart rate data can be used to predict the future heart rate value by time series analysis. The processed heart rate data and the predicted heart rate can then be transmitted to other devices or platforms, including mobile applications or IoT environments, through communication protocols as shown in Fig. 1.

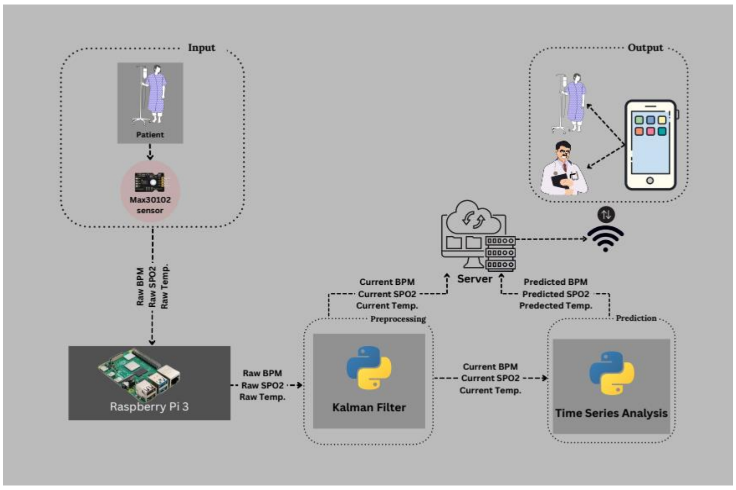

Fig. 1. Block diagram of Heart rate monitoring system

IV. SYSTEM ARCHITECTURE

The design part consists of two sections:

A. Hardware architecture

1) Raspberry Pi 3

A Raspberry Pi 3 is a tiny and budget-friendly computer that can fit in your hand. It's created for diverse projects and educational use. Despite its small size as shown in Fig. 2, it can perform various tasks similar to a regular computer. The Raspberry Pi includes ports for connecting peripherals, GPIO pins for hardware projects, and operates using microSD cards. It serves as a versatile tool suitable for both beginners and hobbyists exploring the realms of computing and electronics. can be seamlessly integrated with a heart rate sensor to form a powerful and adaptable system for heart rate monitoring. By connecting the heart rate sensor to the Raspberry Pi's GPIO pins, the device can capture real-time heart rate data.

2) MAX30102 sensor

Fig. 2 Raspberry Pi 3

The MAX30102 is a compact sensor found in devices such as fitness trackers and smartwatches. It gauges heart rate and blood oxygen levels by utilizing light. Integrating a Photoplethysmography (PPG) sensor and an ambient light sensor, this module emits light into the skin and measures variations in light absorption, allowing for the capture of the pulsatile signal associated with the heartbeat. Equipped with multiple LEDs of different wavelengths, including red and infrared, the MAX30102 ensures accurate readings by compensating for changes in ambient light conditions. Operating through the I2C interface, it facilitates seamless communication with microcontrollers and other devices. The sensor communicates with devices like Arduino and Raspberry Pi using a straightforward protocol. Due to its energy efficiency, it is well-suited for battery-powered devices, and its small size as shown in Fig. 3 makes it easy to integrate into wearables. It is frequently utilized in health-monitoring devices for continuous tracking of heart rate and oxygen levels.

Fig. 3. MAX30102

MAX30102 stands out as the best choice for heart rate tracking systems due to its exceptional combination of features. Its high accuracy in measuring heart rate and blood oxygen levels (SpO2) is crucial for medical-grade applications where precision is paramount. Additionally, the sensor's low power consumption makes it ideal for continuous monitoring without rapidly draining device batteries, ensuring prolonged usage in wearable health devices. The compact size of the MAX30102 facilitates seamless integration into wearable devices, enhancing user comfort and usability. Its digital I2C interface simplifies integration with various microcontroller platforms, making development straightforward for hobbyists, researchers, and developers. The sensor's versatility, capable of measuring both heart rate and SpO2, expands its potential applications in health monitoring. Furthermore, the MAX30102 benefits from a strong community support network, providing ample resources and support for integration and troubleshooting.

B. Software architecture

1) Kalman filter

The Kalman filter is a mathematical tool designed to improve predictions about a system's state, especially when dealing with noisy or uncertain measurements. Developed by Rudolf E. Kalman in the 1960s, it has applications in fields such as control systems and navigation. The filter operates in two main steps: first, it predicts the current state based on past data, and then it refines this prediction using new measurements. By minimizing errors in estimates, the Kalman filter is effective in scenarios involving uncertainty. It is particularly well-suited for systems with linear dynamics and Gaussian noise distribution. It helps obtain the most accurate estimate possible for a system's state. The heart rate values of the patient that were calculated by the MAX30102 sensor before and after the Kalman Filter are shown in Fig. 4. After using the Kalman Filter the data is more accurate than without using the filter.

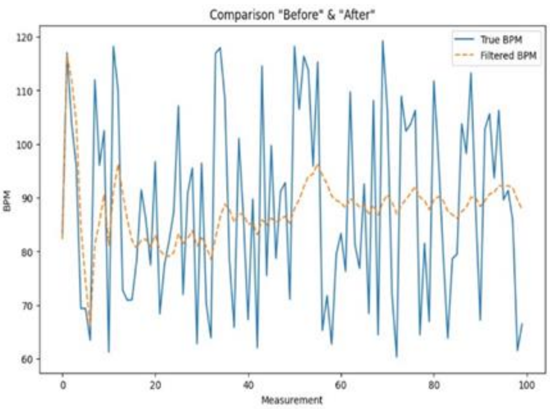

Fig. 4. Before and After applying Kalman Filter

2) Time Series analysis

Time series analysis using the Autoregressive (AR) model is a statistical technique that involves predicting future values in a time series based on past observations. In the context of a heart rate monitoring system, the AR model utilizes historical heart rate data to forecast future heart rate values. The model assumes that the current heart rate is linearly dependent on its previous values, incorporating autoregressive parameters to capture these dependencies. By training the AR model on a dataset of past heart rate measurements, it learns the patterns and trends in the data, allowing it to make predictions for subsequent time points. This predictive capability becomes valuable in anticipating fluctuations and changes in heart rate, offering a proactive approach to health monitoring. The AR model is an essential component in time series analysis for heart rate prediction, providing a tool to extract meaningful insights and support personalized healthcare interventions.

V. IMPLEMENTATION

The MAX30102 sensor is connected to Raspberry Pi as shown in Fig. 5. Sensor readings use I2C communication, namely communication between two ICs using the SDA (serial data) and SCL (serial clock) pins. The voltage used by this sensor is 3.3 volts. The ground in the sensor is connected to the ground in the Raspberry Pi. The SDA pin of the sensor is connected to GPIO 2 Serial Data (I2C) pin in the Raspberry Pi and the SCL pin of the sensor is connected to GPIO 3 Serial Clock (I2C) pin in the Raspberry Pi. The current use of SCL is to control the transmission of sensor data from the sensor via SDA to the microcontroller. The function of this sensor consists of two LEDs, a red LED, and an IR (infrared) photodetector. Photodetectors are located on either side of the probe to capture the light that is scattered and then detected after passing through body tissues. Infrared light is absorbed by hemoglobin, which has a high oxygen content, and hemoglobin, which does not contain oxygen, absorbs red light.

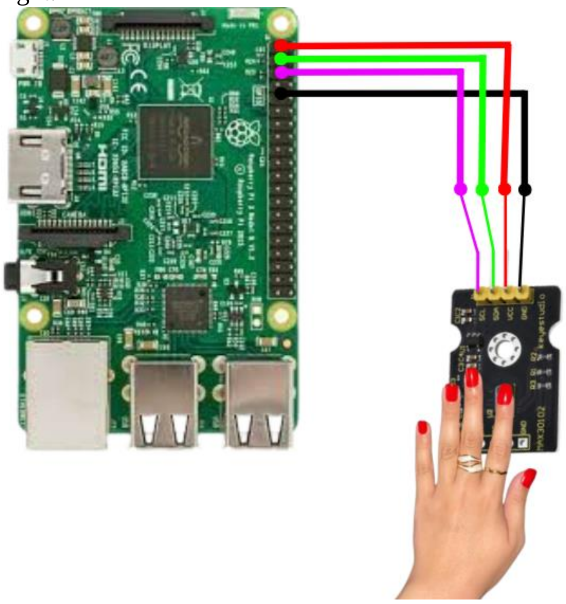

Fig. 5. Fingertip on MAX30102 sensor

When the patient puts the fingertip on the MAX30102 as shown in Fig. 5, the sensor emits light through the skin. By analyzing how blood absorbs this light, the sensor can distinguish between oxygenated and deoxygenated hemoglobin. It then creates a PPG, representing changes in blood volume over time. Using the PPG waveform, the sensor calculates the patient's heart rate and blood oxygen saturation (SpO2). This information is sent to the Raspberry Pi, the next step involves passing this data through a Kalman filter to help enhance the precision of heart rate and oxygen saturation readings by reducing signal noise and errors that may arise from various sources. This filtering process is valuable in obtaining more reliable and stable physiological measurements for further analysis and interpretation.

Once the MAX30102 sensor collects the data, the Raspberry Pi retrieves the raw data, which typically includes measurements such as heart rate, oxygen saturation, and pulse oximetry. This raw data may contain noise or inconsistencies that need to be filtered out for accuracy. To enhance the accuracy of the measurements, the Raspberry Pi applies a Kalman filter, a widely used algorithm for state estimation. The Kalman filter helps in reducing noise and improving the precision of the sensor data by predicting the most accurate value based on the sensor's previous measurements and the system dynamics. After applying the Kalman filter, the Raspberry Pi further calibrates the data before formatting it into a suitable structure for transmission to Google Firebase. This involves converting the data into a JSON (JavaScript Object

Notation) format, which is widely used for data interchange. Additionally, the Raspberry Pi prepares the data for transmission by encrypting it for security and adding metadata such as timestamps for tracking and analysis purposes. This meticulous process ensures that the data collected by the sensor is accurately processed and securely transmitted to Google Firebase for real-time monitoring and analysis.

Using the WebSocket protocol, the Raspberry Pi establishes a secure and persistent connection with the Google Firebase Realtime Database. Once this connection is established, the processed patient data is transmitted in real-time over the WebSocket connection. Unlike traditional HTTP requests, which require establishing a new connection for each data transmission, WebSocket maintain a continuous connection between the Raspberry Pi and Google Firebase, ensuring low latency and efficient data transmission. This real-time transmission allows healthcare professionals to access and analyze patient data as soon as it is collected by the sensor, enabling timely interventions if necessary. The data is securely stored in the Firebase database, where it can be accessed and analyzed in real-time using a web or mobile application. Real-time monitoring of patient vital signs becomes possible, providing healthcare professionals with valuable insights and enabling them to make informed decisions to improve patient outcomes. This real-time communication between the Raspberry Pi and Google Firebase via WebSocket ensures that healthcare professionals always have access to the latest patient data, facilitating better patient care and monitoring.

After the data is filtered and initializing the Firebase Admin and Admin-SDK to access heart rate data stored in Firestore the Autoregressive retrieves heart rate and timestamp data for each user from the Firestore database. (AR) model the uses past heart rate values to predict the future one. After retrieving the data, it creates a Data Frame to organize the heart rate and timestamp data. It performs a quick check for autocorrelation and plots lag plots and autocorrelation plots to visualize the temporal dependencies in the heart rate data. They assign different weights to each past heart rate, capturing patterns in the data. Training involves teaching the AR model by adjusting its internal settings. It learns from historical heart rate data to make accurate predictions by recognizing patterns. To make sure the predictions are on point, we use metrics like Mean Squared Error as shown in Figure 14 the predicted value and 98% accuracy. This helps us understand how well the AR model is doing and guides us in making improvements. Once trained, the AR model can predict future heart rates based on what it learned from the past.

After the AR model accurately predicts your heart rate, the next step involves delivering this valuable information to your mobile app through firebase. This real-time connection ensures that your health insights are instantly accessible on your smartphone. As the AR model forecasts your heart rate, Firebase transmits the predictions to your mobile app, allowing you to receive timely notifications and stay updated on your cardiovascular health trends. This integration empowers you to make informed decisions, whether adjusting your lifestyle or seeking professional advice. The user-friendly interface of the mobile app as shown in Figure 15 provides visualizations and historical data, offering a comprehensive view of your well-being. With a focus on privacy and security, Firebase ensures that your health data is transmitted safely. This dynamic fusion of predictive health modeling and mobile technology creates a future where health insights seamlessly integrate into your daily life, providing a convenient and personalized approach to proactive healthcare.

Fig. 6. Mobile application

VI. RESULTS

The results of 5 different patients in different activity statuses with the information of the patients are shown in the following Table 1. Sensor data after being filtered by the Kalman filter and future predicted heart rate every two hours are also shown in Table 1. Patient 1, Patient 3, and Patient 4 show normal heart rates while Patient 2 and Patient 5 show abnormal heart rates.

Patients	Activity	Gender	Age	Heart Rate (bpm)	SpO2 (%)	Predicted Heart Rate (bpm)
Patient 1	Walk	Female	25	73	95	80
	Run			93	97	94
	Sit			71	98	76
Patient 2	Walk	Male	30	44	87	45
	Run			46	85	48
	Sit			41	90	41
Patient 3	Walk	Female	20	75	96	79
	Run			84	95	80
	Sit			81	97	78
Patient 4	Walk	Male	50	82	97	84
	Run			83	98	85
	Sit			78	97	75
Patient 5	Walk	Male	60	137	87	136
	Run			142	85	139
	Sit			128	91	131

Table 1. Sensor data after being filtered and the predicted value

The patient can access the history of the heart rate and SPO2 from the application, see the next predicted value of heart rate and check if the heart rate range is normal or abnormal through the application. If the patient's heart rate is abnormal then the application sends a notification to the patient and can contact any emergency doctor or any family member. The patient’s doctor can reach the heart rate and oxygen saturation changes through the monitor screen.

VII. CONCLUSION

This paper presents a heart rate and oxygen saturation monitoring system using Raspberry Pi, MAX30102 sensor, Kalman filter, and time series analysis which is a powerful and effective solution for real-time health tracking and predicting heart rate. The Raspberry Pi handles the data processing, the Kalman filter improves measurement accuracy, and time series analysis predicts future heart rates based on historical data. Firebase ensures smooth communication between devices for remote monitoring. This system helps to monitor heart rate and oxygen level of individuals who are unable to make regular visits to hospitals, simplifying primary health checkups. Storing patients' medical history on the server facilitates follow ups. By leveraging information technology, the system eliminates human errors, leading to improved performance.

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A virtual pet for children with autism spectrum disorders (ASD)

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***Abstract*— In Egypt, about 33.6% of children with developmental disabilities have Autism Spectrum Disorder (ASD), social challenges are particularly acute for those with Asperger syndrome, often leading to marginalization and limited opportunities. This project proposes an innovative solution: an Android application featuring an interactive virtual pet companion powered by augmented reality (AR). Developed with the Unity game engine and MediaPipe for pose estimation, the app aims to provide a safe and engaging platform for children with Asperger syndrome to practice social interaction, develop emotional learning skills, and combat social isolation. This project targets children aged 5-12, seeking to improve their social skills, emotional regulation, and engagement with their surroundings through playful interaction with the virtual pet. By addressing the unique needs of children with Asperger syndrome in the Egyptian context, this project has the potential to foster their social integration and well-being, paving the way for a more inclusive future. Evaluation reveals promising results (software-wise), with a 92% effectiveness rate in guiding users toward goals, 93% efficiency in resource utilization, and manageable technical performance.**

Keywords—Augmented Reality (AR), Autism Spectrum Disorder (ASD), Asperger syndrome, Extend Reality (XR), MediaPipe, Unity game engine.

I. Introduction

According to the World Health Organization (WHO) **Autism spectrum disorders (ASD)** are neurodevelopmental disorders, meaning they are caused by abnormalities in the way the brain develops and works [1]. Early diagnosis of ASD is crucial for early intervention and better prognosis. However, it is often delayed until preschool or school age. [2]. Asperger's syndrome is an ASD subtype that this project focuses on in its first phase. Individuals with Asperger's syndrome experience difficulties with social communication and interactions, including verbal and non-verbal communication, and may have peculiar behaviors, such as stereotypies and limited interests [3].

In Egypt, the prevalence of ASD among children with developmental disorders in Egypt was documented to be 33.6% most of the children diagnosed with autism came from families of low socioeconomic status [4]. Today, access is limited by geography, socioeconomics, or global health concerns such as the COVID-19 pandemic, and having mobile healthcare solutions that work beyond traditional clinical settings can ensure access to quality care [5] and studies show that games help improve the social and emotional skills of people with autism [6]. Existing solutions for ASD intervention often rely on clinical settings or expensive equipment, limiting accessibility [3]. This project focuses on mobile healthcare solutions, leveraging the high prevalence of mobile phones to deliver interventions directly to users. Additionally, the project incorporates gamified training programs, a well-established technique for improving social and emotional skills in a fun and engaging way [6] [7]. By combining mobile accessibility with gamified training, this project offers a novel and potentially transformative approach to ASD intervention.

It is worth noting that almost everyone has access to mobile phones, with Android phones being the most widely used. This Android app, developed with Unity, a popular game engine for augmented reality (AR), uses ARCore to bridge the physical and virtual realms. By tracking body movements through MediaPipe and translating them into data points, the app lets users with Asperger's syndrome interact with virtual objects in an AR environment, promoting independence and social inclusion globally.

This paper is organized as follows: section 2 contains a summary of the lecture review. Section 3 contains how the application is implemented, section 5 is a methodology, and finally, section 6 shows the evaluation of the application. In conclusion, this study is finalized in section 7

II. Literature review

In recent years, virtual pets have emerged as a potential therapeutic tool for children with ASD. These interactive companions offer several advantages, including providing companionship, promoting social-emotional learning, and reducing anxiety and stress. This literature review critically examines the existing research on virtual pets for children with ASD, exploring their potential benefits, limitations, and underlying mechanisms of action.

A. Positive Impact

Studies have shown that virtual pets can positively impact children with ASD. Below are the key findings:

1) ***Improved social engagement and communication***: A study published in the Journal of Autism and Developmental Disorders in 2019 revealed that children with ASD significantly improved their social engagement and communication skills after interacting with a virtual pet for 12 weeks. The study used Paro, a plush robotic seal that responds to touch, voice, and gaze through sensors and actuators. The children who interacted with Paro exhibited increased initiations of interaction and turn-taking behavior. Specifically, they showed increased

initiations of interaction, turn-taking behavior, and joint attention [8].

2) ***Reduced anxiety and stress***: A 2020 study published in the International Journal of Play reported that children with ASD used a virtual pet app on tablets. The app featured an animated dog that responded to the child's touch and voice, offering companionship, and promoting relaxation. companion showed reductions in anxiety and stress levels, as measured by physiological indicators like heart rate. Additionally, they reported feeling calmer and more comfortable in social situations [9].

3) ***Enhanced empathy and compassion***: A 2022 study published in the International Journal of Human-Computer Studies investigated the use of a virtual pet application on empathy development in children with ASD using a smartphone app featuring a virtual pet dog alongside interactive stories and games focused on emotions. The results showed that children who interacted with the app demonstrated increased prosocial behavior and empathy towards others, indicating a potential transfer of learned empathy skills to real-world settings [10].

B. Beyond the Benefits

While these findings highlight the potential of virtual pets, it is crucial to acknowledge their limitations. Studies have yielded mixed results, and concerns regarding social isolation and limited generalizability to real-world interactions remain. Individual differences in learning styles and symptoms also play a role in effectiveness. Therefore, careful monitoring and integration with other therapeutic interventions are essential for successful implementation.

Despite these challenges, virtual pet interventions offer a unique, interactive, and personalized approach to traditional ASD therapy. They promote empathy, positive behavior, and emotional growth, and cater to individual needs. Further research is needed to explore different virtual pet designs, functionalities, and applications, refining their efficacy and generalizability.

III. IMPLEMENTATION

This section outlines the implementation process of a virtual pet app that utilizes Unity, ARCore, and MediaPipe for body detection and object manipulation. However, this project does not require any hardware parts.

Augmented Reality (AR) technology involves the integration of virtual objects and other digital content including images with physical or real-world content [11]. AR enables us to overlay virtual objects onto real-world surfaces with precision, creating an illusion that they exist in the same space. This enhances the realism and interactivity of the AR experience significantly. It is widely known that the Unity and Unreal game engines are the most powerful tools available for designing AR environments. Compatibility with available computer resources, including RAM, memory, and graphics card, led to the selection of the Unity game engine for this project. Below is a description of each technology and its respective role in the project.

A. Unity game engine

Unity game engine that is widely used for creating and operating interactive, real-time 3D content. The platform offers a range of software solutions to develop, run, and monetize interactive, real-time 2D and 3D content for various devices such as mobile phones, tablets, PCs, consoles, and augmented and virtual reality devices. ARCore is an AR platform API specifically designed for Android apps and serves as a foundational technology within this project. The purpose of using ARCore is to project a virtual pet and your body pose onto the real-world environment. For this project, I utilized Unity version 2021.3.17f1 along with the XR-Plugin version 4.3.

B. Unity UI Toolkit

Unity UI Toolkit is a framework designed for building user interfaces (UI) in Unity, offering a more flexible, modern, and performant approach than the legacy Unity UI system. Key features include the UI System, which uses a visual hierarchy of elements, a declarative syntax (UXML) for layout and visual structure, and a style sheet language (USS) for styling elements. This toolkit has modern architecture, flexibility, performance optimization, and ease of use.

C. Unity Machine Learning Agents Toolkit

ML-Agents is an open-source kit that allows games and simulations to serve as environments for training intelligent agents. The toolkit supports popular RL algorithms like Proximal Policy Optimization and Soft Actor-Critic. Using them, a virtual pet can be developed that is tailored to each child's needs based on the severity of the disorder.

D. MediaPipe

MediaPipe Pose estimation is a vital tool for capturing real-world object data. By keeping track of the key points and dimensions of real-world objects, MediaPipe provides the necessary information for virtual material placement and manipulation. This ensures a natural and intuitive interaction with the AR scene.

E. Programming languages

For this project, C# Script was utilized to interact with Unity on a Visual Studio IDE. Python 3.11.4 was also used to implement and control the MediaPipe pose estimation framework and transmit points back to Unity. These languages were chosen for their dependability and widespread use.

IV. METHODOLOGY

This section presents the project in three stages. The first stage involved designing a prototype, which was not evaluated on children. The prototype includes activities suitable for children with Asperger syndrome, such as playing with cubes with a virtual pet, and simple exercises like raising hands. It also features emojis and words that express feelings.

The second phase incorporates educational games for the Arabic language. The third phase aims to expand the application to cover a wider range of ASD.

The application boasts unique machine-learning capabilities that allow the virtual pet to recognize each child's needs and adjust its behavior accordingly. As the child spends more time with the application, the virtual pet's experience will grow, making it more effective for individual cases of autism spectrum disorders. These features will be explained in more detail in the following sections.

A. System Architecture

The application's architecture comprises three core modules. representing body pose. Secondly, Virtual Pet Behavior leverages the extracted body pose data to dynamically control the virtual pet's movements, animations, and responses based on the child's actions. Lastly, Object Manipulation maps specific body gestures to trigger interactions with AR objects, enabling children to manipulate them through their movements. The application ran smoothly on all tested devices with minimal lag or technical issues. The AR integration provided a stable and immersive experience for users.

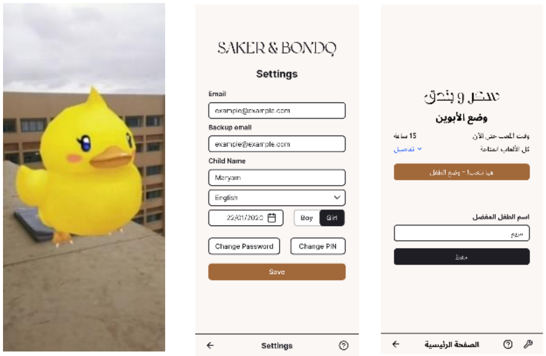

Fig. 1. Random screenshots of the application interface during the initial development stages.

B. Plugin Mediapipe into Unity

This section dives into the technical heart of the project, unveiling how various technologies seamlessly cooperate to manipulate materials in real time, responding to both hand gestures and the surrounding environment.

There are two key steps:

1) ***Capture***: A camera captures real-world video. MediaPipe Pose within Unity (using Python bindings) detects objects and body positions. User input directly controls virtual materials.

2) ***Hand Tracking***: MediaPipe's hand skeleton model tracks user hand movements. Preprocessing cleanses data for accurate pose detection. Key points, angles, and orientation guide AR interactions. The virtual pet responds to specific hand movements.

Fig. 2. MediaPipe landmarks for body

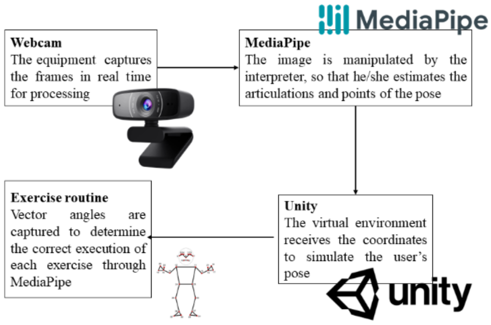

Fig. 3. Block diagram of application core

C. User Interface

While effectiveness dominates design in most Android apps, especially prototypes, a different approach is crucial for apps aiming to serve unique user groups like children with Asperger's syndrome. Their strong visual-driven nature necessitates a carefully crafted interface rich in colors and engaging graphics. Furthermore, supporting the Arabic language necessitates additional UI considerations.

This section delves into the distinguishing features that set this application apart from regular games, highlighting how its interface caters to the specific needs of its target audience.

An outline was created for the UserFlow diagram, and the login process was designed in Figure 1. Parents must log in to their account, followed by their child's pet account for a safer and monitored environment. Figma was used for designing wireframes and prototypes using happy colors like yellow and blue preferred by children with Asperger's, [3] along with big fonts and shapes to make the app more user-friendly.

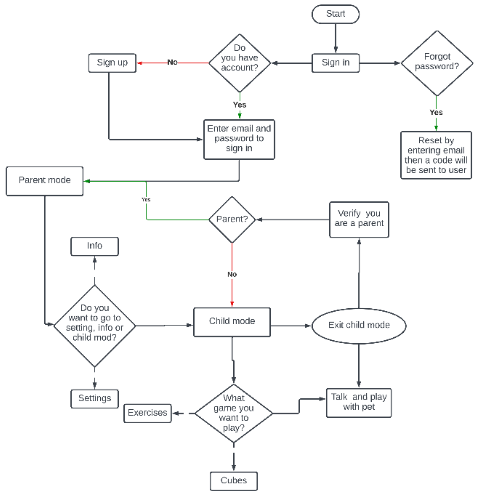

Fig. 4. UserFlow Diagram

D. Interaction Design

This section focuses on the crucial aspect of designing interactive experiences for augmented reality applications that feature virtual pets for children with ASD.

To ensure a positive experience, it is important to create virtual pets that are both engaging and relatable. The game should have simple and intuitive gestures that allow children to easily access different abilities. Giving children the option to choose a name for their virtual pet and even selecting a name that their pet prefers to call them can make them feel more connected to the game which achieves the persona concept.

To keep children motivated and engaged, the game has plenty of activities and challenges such as puzzles, cubes, and physical exercise. Additionally, children should receive rewards and achievements to celebrate their progress and reinforce desired behaviors.

E. Virtual Pet and Artfiial intallgent

Unity itself offers built-in features like navigation meshes for pathfinding, animation blending for smooth character movement, and physics simulations that can benefit from machine-learning techniques for enhanced realism and interactivity. This suggests that unit ML tools could at least theoretically be used to create virtual pets specifically designed for each child, helping to achieve persona concepts.

Unity ML-Agents Toolkit provides a wide range of services, but this project focuses on customizing (persona concept) the virtual pet. The pet must learn whether the child is progressing or not. The virtual pet goes through a large number of convolutional networks that make it automatically create imaginary scenarios and train on them based on what it receives, which means that The longer the application is used, the more the virtual pet learns.

V. EVALUATION

Under the ISO 9241-11:2018 standard, this section explores usability metrics aligned with the core principles of effectiveness, efficiency, and satisfaction. While the app hasn't been tested with autistic children due to certain limitations, local doctors have expressed positive feedback, suggesting it could be a promising tool for this population.

A. ***Effectiveness or (Accuracy)***: The task Completion Rate is used to measure and evaluate a child's interaction with a virtual pet, object manipulation, or specific game objectives. It determines the accuracy and completeness with which users achieve special goals. Effectiveness, a percentage of successful users, is calculated by dividing successful completions by total users. Then, overall integral product effectiveness E will be calculated as shown in equation .1.

$$E = \frac{number\ of\ task\ completed\ successfully\ for\ all\ users}{total\ number\ of\ tasks} \times 100 \qquad (1)$$

Designed ten different tasks with varying levels of difficulty to assess the effectiveness of the application. Fifty participants completed these tasks. The results indicate that the overall effectiveness of the prototype is 92%, which is considered acceptable. The application helped users select the appropriate value for their use and choose the appropriate scenario for each user from a variety of proposed scenarios.

B. ***Efficiency***: defined as the number of resources used by the user to achieve their goals accurately and completely, according to the application. Regarding software products, time is the most valuable resource to measure efficiency in terms of task time. The overall efficiency of a product is calculated as the percentage of time taken by participants to complete a task compared to the total time taken by all participants, whether the task was completed successfully or unsuccessfully as shown in equation .2.

$$F = \frac{total\ time\ of\ task\ completed\ successfully\ for\ all\ users}{total\ time\ of\ tasks} \times 100 \qquad (2)$$

The results show that the overall efficiency of the prototype is 93% which is a high value.

C. ***CPU and memory usage***: it refers to the resources your computer utilizes when running applications and processes. CPU usage is the percentage of processing power the computer utilizes, while memory usage represents the amount of RAM used by applications and processes. It is essential to monitor these resources to ensure optimal performance. The prototype's CPU usage is 21.5%, falling within the range of normal activity. Memory usage is 56.5%, also aligning with typical usage expectations [12].

TABLE I. RESULT SUMMARY

	Effectiveness	*Efficiency*	*CPU usage*	*Memory usage*
Result	**92%**	**93%**	**21.5%**	**56.5%**
Indicating	Acceptable	High	Normal	Normal

VI. CONCLUSION

This project presents a novel virtual pet application built with augmented reality and MediaPipe for body detection, aimed at engaging children with ASD and potentially improving their emotional and behavioral development. The prototype successfully captured children's attention and achieved an impressive 93% efficiency and 92% accuracy in its initial model. While these results are promising, further refinement is needed. Future iterations should prioritize enhancing the accuracy of individual virtual pet interactions, particularly in body and behavior detection. Additionally, conducting long-term studies will be crucial in evaluating the sustained effectiveness of such applications on children with ASD.

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