Leveraging AI to Enhance Doctor Availability in Hospitals

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ABSTRACT

Optimizing doctor availability and appointment allocation is pivotal for improving patient care and hospital efficiency. Our innovative approach leverages digital technology and AI integration to streamline the appointment scheduling process, significantly enhancing the overall patient experience. Our solution's core is a user-friendly application designed for effortless appointment scheduling. Patients can easily book appointments, specify preferred time slots, and promptly receive confirmations, simplifying the journey for both patients and medical staff. We utilize a comprehensive tracking system to keep patients informed about doctor availability, integrating ML algorithms for heightened accuracy. Additionally, our system incorporates a secure payment gateway, enabling patients to make hassle-free payments for appointments directly through the application, enhancing convenience. This payment system also identifies false requests and applies appropriate penalties. This system dynamically adjusts appointment slots based on real-time doctor availability and patient symptoms, ensuring patients receive accurate appointment time estimates, minimizing wait times, and ultimately elevating the overall patient experience.

General Terms

ML Algorithms, Appointment Scheduling, Payment Verification

Keywords

RFID, Wifi RTT, Object Detection, Dequeue Algorithm

1. INTRODUCTION

The advancement of technology has significantly influenced various sectors, including healthcare. Addressing the demand for healthcare services while ensuring efficient and timely access to medical care has become a major concern. To overcome this problem, a practical approach is needed that integrates real-time data analysis and artificial intelligence (AI) to optimize doctor availability and appointment booking. This research paper explores the potential of AI to transform patient interactions with healthcare providers, streamline appointment scheduling, and improve overall healthcare accessibility.

Patients want convenient and timely access to healthcare professionals nowadays. However, traditional appointment scheduling systems often face challenges, leading to prolonged waiting times, scheduling conflicts, and ineffective allocation of medical resources. By leveraging the capabilities of AI and real-time data, we propose a shift in healthcare appointment management, aiming to improve the patient experience and bridge the gap between patients and doctors.

This paper delves into the exploration of optimizing doctor availability and appointment booking through the analysis of live data streams, patient preferences, historical scheduling patterns, and resource allocation. We highlight the benefits of integrating AI-driven solutions into the healthcare ecosystem, such as improved resource usage, better scheduling accuracy, reduced patient waiting times, and ultimately, a patient-centric approach to healthcare delivery.

The model can also be incorporated with prioritizing senior citizens and patients based on the severity of their symptoms which other systems lack we have added a payment portal with a penalty algorithm to improve the user base adding to that our proposed system can work on three stages of live data to increase the accuracy of doctor's availability which helps the algorithm to provide more accurate waiting time, this model may help millions of patients and many hospitals with queuing time.

2. METHODOLOGY

2.1 Using Wifi-RTT(Round-Trip-Time)

Wi-Fi RTT allows devices to accurately determine their location in the hospital with a precision of 1-2 meters by measuring the distance to the access points i.e. Wi-Fi routers. [3]

In indoor positioning, Wi-Fi RTT technology relies on the Fine Timing Measurement (FTM) protocol. This important element utilizes precise measurements of round-trip times of Wi-Fi signals to calculate distances and accurately locate devices within Wi-Fi networks. Several location-based services and applications, including interior navigation and asset tracking, heavily rely on this technology for their proper functioning.[**?**]

The FTM protocol operates where the initiating device, typically a smartphone, sends a request to the access point (AP) supporting RTT. The protocol follows these steps:

(1) The smartphone initiates contact with the RTT-enabled access point through an FTM request.

(2) A timed FTM message exchange between the access point and the smartphone is initiated.

(3) During this exchange, each transmission and reception of FTM messages are timestamped by both the access point and smartphone.

(4) These timestamps play a vital role in computing time-related parameters. [8]

The FTM determines parameters associated with time:

(1) *Time of Arrival (ToA)*: The moment when the signal reaches the smartphone.

(2) *Time of Departure (ToD)*: The moment when the signal leaves the transmitter.

(3) *Time of Flight (ToF)*: Representing the time required for the signal to cover the distance from the transmitter to the receiver.

The ToF is calculated using the equation:

$$\text{ToF} = \frac{(t_{2\text{ToA}} - t_{2\text{ToD}}) + (t_{1\text{ToA}} - t_{1\text{ToD}})}{2} \quad (1)$$

[3]

In (1) where tToA1, tToD1, tToA2, and tToD2 are timestamps (ToA) symbolizing Time of Arrival and (ToD) symbolizing Time of Departure measurements for the first and second sets of data from respective access points.

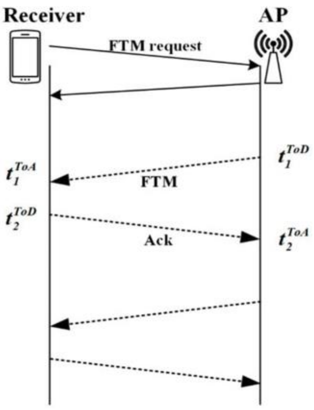

Fig. 1. The fine timing measurement (FTM) protocol.

Least Square (LS) algorithm is the optimization technique well-known for WiFi-RTT placements. [3] In-range measurements between a smartphone and access points (APs) in an interior environment, reduce the sum of squared inaccuracies. The exact location of the smartphone is determined by crossing the circles that stand in for these range measurements, which enables accurate indoor positioning.

2.2 Using Object Detection Model

YOLO, the abbreviation for 'You Only Look Once' is an algorithm used for object detection, predominantly based on Convolutional Neural Networks(CNN). It is not one of the most accurate but it is quick in terms of detecting the object. The speed is much more needed in this case because the setting of the cabin isn't mobile which would in turn result in inaccurate results instead it

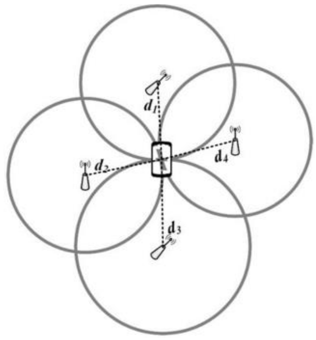

Fig. 2. The positioning principle of the LS algorithm.

consists of the same setting throughout in which the patient's chair if occupied would indicate the doctor to be busy or else available if the chairs are unoccupied. Compared to recognition algorithms, detection algorithms forecast class designations and identify object positions.[5]

The input includes a batch of images, arranged as (m, 416,416, 3), where 'm' symbolizes the number of images, 416 x 416 represents image dimensions, and 3 signifies the color channels (e.g., RGB). For the output, it involves a series of bounding boxes combined with the particular predetermined classes. Each bounding box is denoted by six numbers: (PC, bx, by, bh, bw, c). Consequently, the output materializes as a feature map. The critical point to observe is that due to the utilization of 1 x 1 convolutions, the prediction map is precisely the same size as the feature map preceding it.

Determining the specific width and height of bounding boxes can introduce instability in gradients during training. To resolve this, modern object detectors often choose to forecast log-space transformations or offsets relative to pre-defined default bounding boxes, referred to as anchors. These forecasted transformations are then applied to the anchor boxes, resulting in the final prediction. [5]In YOLO v3, three anchors are used, resulting in the prediction of three bounding boxes for each cell in the prediction map. The following formula describes how the network output transformed to obtain bounding box predictions:

$$b_x = \sigma(t_x) + c_x \quad (2)$$

$$b_y = \sigma(t_y) + c_y \quad (3)$$

$$b_w = p_w e^{tw} \quad (4)$$

$$b_h = p_h e^{th} \quad (5)$$

[5]

The variables in (2) (3) (4) (5) bx, by, bw, and bh are the center coordinates of x, y, width, and height of our prediction. is The network outputs are tx, ty, tw, th (xywh). cx and cy are the top-left coordinates of the grid. pw and ph are anchor dimensions for the box. In the domain of optimizing doctor availability within healthcare, the utilization of the YOLO algorithm for object detection offers an optimal solution. The objective is to detect the presence of a doctor in their office or ascertain the occupancy status of patient's chairs, thereby determining the doctor's availability. An image of the doctor's office or waiting room is processed in a grid-like fashion, with each grid cell representing a distinct region of interest within the image. For a standard image size of 416x416 pixels, the YOLO al-

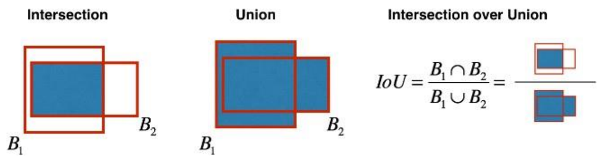

Fig. 3. Intersection over Union

gorithm predicts a substantial number of bounding boxes (10647 in this instance) across the various grid cells.

The process is adapted as follows to suit the healthcare context and efficiently assess doctor availability:

(1) *Object Detection using YOLO:* Employ the YOLO algorithm to predict bounding boxes for chairs, symbolizing patients, and a designated region representing the doctor's chair. [10]

(2) *Box Filtering based on Objectness Score:* Filter the predicted bounding boxes based on their associated objectness scores. Bounding boxes with low objectness scores, indicating lower confidence in detecting a chair or the doctor's chair, are disregarded.

(3) *Non-maximum Suppression (NMS):* Implement Non-maximum Suppression to handle multiple predictions or overlapping bounding boxes for the same chair or doctor's chair. Calculate the Intersection over Union (IoU) for the bounding boxes, considering their coordinates. Retain only the bounding box with the highest confidence (score) and eliminate the others if significant overlap is detected.[10]

(4) *Determining Doctor Availability:* Post NMS, determine doctor availability based on the remaining bounding boxes. If the doctor's chair is occupied (detected), the system designates the doctor as "not available." If patient chairs are occupied (detected), the system designates the doctor as "available."

This tailored approach, employing the YOLO algorithm and subsequent processing, effectively gauges doctor availability by detecting the presence of the doctor in their office (occupied doctor's chair) or the presence of waiting patients (occupied patient chairs). This enables streamlined appointment scheduling and optimal utilization of medical resources while ensuring an efficient and accessible healthcare experience.

2.3 Using NFC

NFC, short for near-field communication, is a wireless interaction interface. NFC operates in a field of around 10cm. The time required for the transfer of information and setup time is below 0.1s.In our proposed solution, every OPD will be equipped with an initiator that will work in an active mode and will only have one target at a time, and the target will be an NFC tag, which will be carried by every doctor.[2] Let's discuss the NFC-based OPD detection of Doctor with the help of a flowchart mentioned above: [2]

(1) Each doctor carries an NFC tag, which acts as a target device. These NFC tags contain unique identification information specific to each doctor. When a doctor taps their NFC tag onto the initiator (an NFC reader or scanner), several technical processes are initiated.

(2) The NFC initiator detects the presence of the doctor's NFC tag within its proximity.

(3) The NFC initiator reads the unique ID stored on the NFC tag. This ID serves as the doctor's identifier. [9]

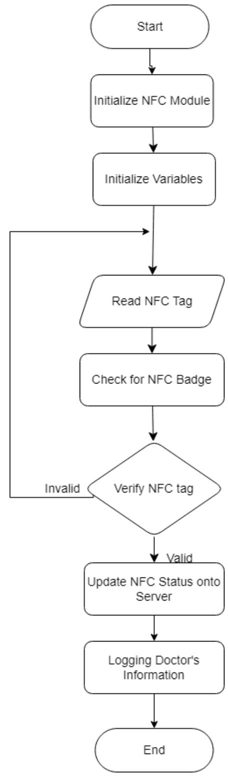

Fig. 4. Use of NFC-tags for Detection.

(4) Alongside the ID retrieval, the NFC initiator can capture spatial location data. This data can be obtained using location-aware technologies, such as beacon systems.

(5) The captured location information is associated with the doctor's NFC tap and can be stored and updated in the system.

(6) The system interfaces with a database where doctor information is stored.

(7) The unique ID retrieved from the NFC tag is used to query the database to identify the doctor associated with the tag. [9]

(8) The database contains a status field for each doctor, indicating their availability.

(9) Upon the first tap of the doctor's NFC tag, the system updates the availability status to reflect that the doctor is unavailable (e.g., "Busy" or "Not Available").

(10) If another tap of the same doctor's NFC tag is detected while their status is marked as unavailable, the system interprets this as an availability update.

(11) The availability status is then changed to indicate that the doctor is now available (e.g., "Available" or "Free").

All interactions, including doctor identification, spatial location, and status updates, are logged in the database for auditing and tracking purposes.

3. SYSTEM DESIGN

As we understood from the individual explanations of the technology we are using, let's proceed forward to understand the workflow. The flowchart starts at the user's end, where the user selects his/her preferred hospital, and OPD, and progresses towards selecting the doctors, to select the doctors we need to check the doctor's availability, and the system does it in three ways.

(1) Wifi-RTT, checks the distance of the doctor's device from the access point.
(2) Face detection to see if the doctor is present, where YOLO will be used to check the availability.
(3) RFID card scan to read the frequency and check if the doctor is available at the OPD.

Using the below flowchart, we would have a broad idea of how the model will work.

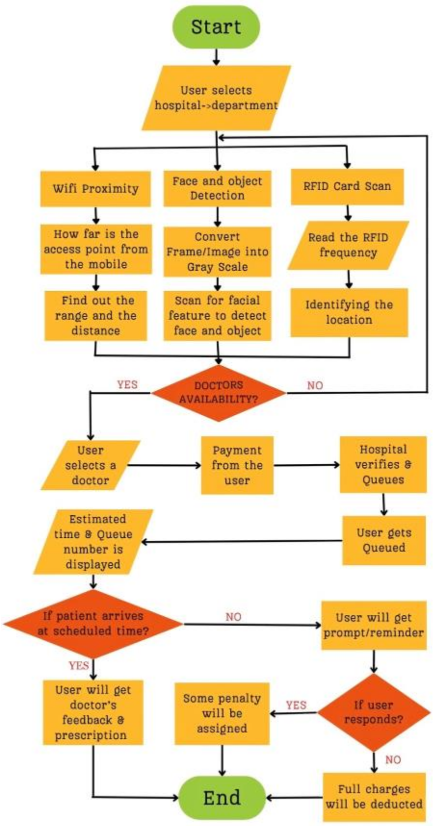

Fig. 5. Flowchart

Thus, the three available ways for determining doctors' availability will update live data if any of it comes out false, the system will keep updating it for that specific data. Now when a doctor is available, the user can select a doctor. While entering the queue, the request will first be intercepted by the hospital's admin and they can assign and change the priority of the patient based on the severity of their symptoms, the user will have to first pay the appointment fees, and false requests will be penalized with the penalty algorithm.
The penalty algorithm will check if the patient has arrived at the hospital if the value is passed as false to the penalty algorithm, The algorithm will prompt the user on their device. If the user responds to the prompt but is unable to appear on the same day, a penalty will be imposed. If the user chooses to arrive late, they will be de-queued and re-queued. If the user does not respond to the prompt, the hospital's specified charges will be applied.

3.1 Database Schema

This database schema contains details of Hospital logs that include tables for doctors and admins. The doctor table contains details such as DoctorID, Name, Expertise, Presence in the hospital, and assigned patient. Patient details are associated with doctors through the patient appointment table, which includes patient disease details. The admin table contains admin and hospital details, updated from the hospital table. The admin table includes a user details table that contains feedback and prescription information. Live data of doctors is updated with additional patient details, such as patientID, Appointment Date, Department of the Doctor, doctor's Prescriptions, payments, and a feedback mechanism for patient queries and support. Doctor's presence is updated in the 'doctors presence' table which is updated with NFC, WifiRTT, and face and object detection, Admin table has access to all the databases, admin can update things in the doctor table, in the hospital table, and also in the patient's table to update prescription and next appointment reminder

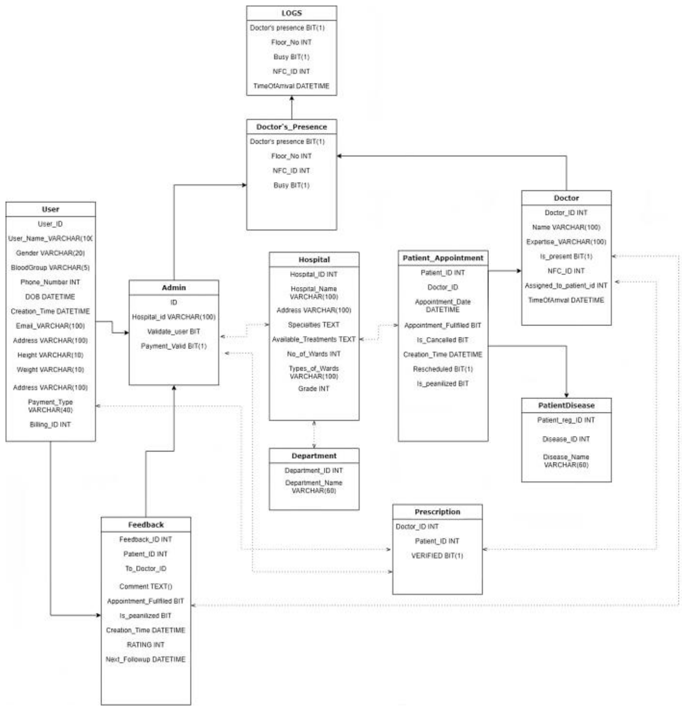

Fig. 6. Database Schema for Hospital Appointment Allocation.

3.2 Block Diagram

The block diagram below shows how our system works together and how it would respond when it is given input from the users. On the User side, the patient would log in with the personal details of Age, Symptoms suffered, and Severity of the symptoms. Following this, the system Side will determine the distance of the access point, detect the occupancy of the chair, read the NFC frequency to identify the doctor's location, and determine if the doctor is available or busy. On the other hand, the admin will see doctor availability which helps in doctor allocation. Admin will verify the payment to queue the patient at a scheduled time and also send reminders, the user will get follow-up reminders where the user will simply visit the hospital at their scheduled time and get a prescription or the user can respond to reschedule the appointment. If the user doesn't respond to the reminder, then the admin will mark the patient as absent and the algorithm will charge a penalty.

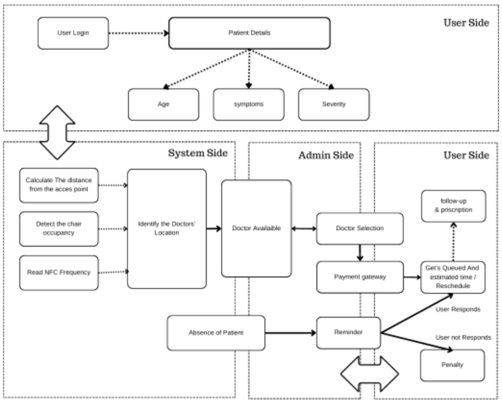

Fig. 7. Block Diagram

4. RESULTS AND DISCUSSIONS

4.1 Results

In this research, we found that integrating AI into hospital management can significantly reduce the patient's wait time. Using the algorithms in the CNN and YOLO v8 models, we can use object detection in a doctor's cabin and label the different objects in the cabin. One object that contributes every time to determining the availability of the doctor is the occupancy of the chairs in front of the doctor's desk. If such chairs are occupied, the doctor would be tagged as busy. However, developing a model completely dependent on such object detection can cause discrepancies, and the chair can be occupied by other hospital staff. In such cases, the wrong data would be taken as input. Therefore, integrating such data into the systems of WiFi-RTT and RFID would provide higher accuracy. The connection between the doctor's phone and the WiFi source can be used to calculate the distance of the doctor to their OPD. Also, a penalty algorithm will be implemented to deduct monetary charges from patients in cases of false appointments.

Penalty Algorithm

Step 1: Start
Step 2: Receptionist updates if the patient has checked in
Step 3: if yes, Jump to step 8
Step 4: if no, the patient will be prompted for a reminder
Step 5: If the patient responds and assures that they'll be coming on the same day of queuing, they'll be re-queued.
Step 6: If they respond but cannot show up on the day some penalty amount will be charged.
Step 7: if they do not respond at all, the total booking fee will be charged
Step 8: End

4.2 Discussions

The proposed model integrates further methodologies, utilizing object detection, Wi-Fi RTT for precise hospital localization, and NFC technology to monitor doctors' presence in their respective OPDs. This sets it apart from existing models primarily focused on patient queuing using NFC alone.
Moreover, it offers a comprehensive application enabling patients to schedule appointments based on doctors' availability. Additionally, patients can access their reports, prescriptions, and feedback system. The system also includes a payment gateway for upfront payments by patients.

5. LIMITATIONS OF THE PROPOSED MODEL

Our proposed system relies heavily on Yolo object detection. There might be a case where the doctor's seat may be occupied temporarily by the other medical staff since our system doesn't deal with identifying the doctors. In this case, our system may incorrectly access that the doctor is busy and can update the availability of the specific doctor's status to busy.
WiFi RTT also plays an important role because it is responsible for identifying the local position of the doctor and updating it accordingly. The doctor may not choose to carry his or her mobile device within the hospital, thereby keeping it in their OPD. This can also incorrectly update the doctor's position, and for Wifi RTT to function, doctors must always carry their devices within the hospital.
Also, the doctor's device may not be connected to the nearest access point when the doctors are continuously change places, resulting in an incorrect update of values and requiring doctors to keep track of the connected access point.

6. CONCLUSION

In conclusion it is possible to optimize the doctor's availability and appointment booking in hospitals, through newer technologies, we can use live data and technologies like wifi-RTT, RFID, and object detection to get live data. Now we can use this data and update the doctor's availability live to the patients so they can get quicker treatment at the same time to minimize the inconvenience of both, hospitals and patients. A penalty algorithm like ours can be added so patients will only queue themselves if they can reach there in time thus making it a secured platform for actual patients in need. To make it a better ecosystem we have added prescription updating, next appointment date reminders, and a priority queue based on age and severity of the symptoms. Furthermore, integrating a user-friendly application would enhance the patient experience, allowing them to schedule appointments, receive live updates, and access past medical records. Additionally, incorporating machine learning algorithms could predict peak times and how much time a doctor can take for a patient, enabling proactive resource allocation. Implementing telemedicine features would further streamline the process, providing remote consultations and reducing physical traffic in hospitals. Moreover, ensuring data security and privacy through robust encryption protocols is imperative. Continuous feedback loops and data analysis can refine the system, optimizing resource utilization and improving overall healthcare efficiency.

7. FUTURE WORK

In the future, the system will be available on every device for ease of accessibility, Furthermore, a facial recognition model can also be added alongside Object detection to recognize and identify doctors within the OPD to avoid incorrect updates to the doctor's availability when someone has taken over doctor's seat temporarily. A separate section can be added for the patients where they should be able to update the existing medical reports and their symptoms.

ACKNOWLEDGMENT

We remain immensely obliged to Dr. Nandini Chandra Nag for her invaluable support in gaining insightful solutions and resource-gathering during the research work.

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