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Reducing NHS Waiting Times Through Technological Innovation A Proposal for an AI-Driven Patient Flow Optimization System (AIPFOS)

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Abstract- The present study aims to develop a new AI system to solve the problem of such excessive waiting times in the National Health Service (NHS) through the development of the AI-Driven Patient Flow Optimization System (AIPFOS). It includes AI triage, staffing forecast, intelligent queuing, teleconsultation, bed tracking, and healthcare data stored on a blockchain. The study also discusses the shortcomings of the existing systems like EMIS and the NHS App which is followed by the proposed four-step plan for the implementation of the proposed system. Advantages, issues and prospects, as well as a brief financial plan is described to show a practical and evolutionary vision for improving the quality of patients' treatment and increasing the eflectiveness of logistic processes.

Index Terms—NHS waiting times, AI triage, patient flow optimization, Node.js/Express, ReactJS, digital health, FHIR interoperability, ethical AI in healthcare

I. INTRODUCTION

The NHS is an important institution in the United Kingdom, which is charged with delivering health care services to people in the country. However, over the last few years, waiting has been a persistent factor that impacts the satisfaction level of the patient, health status, and systems. Evaluations of coverage and quality from British Medical Association (BMA) and NHS England reveals increasing worries over the timeliness of patient's care this being in A&E and access to GP (Moore, 2022). These delays are not simplistic or in the administrative nature; they come with significant impacts. At the societal level, they raise stress levels and reduce the public's confidence in health facilities. From an economic perspective they have intangible costs such as loss of working time and the length of time a patient needs to spend in seeking treatment. From the patient's viewpoint, it means that the treatment starts after time is lost, health deteriorates, complications set in and mortality rises.

Therefore, this research explores the possibility of developing a new technological system in the context of the NHS delivering the patient flow improvement services that, in turn, would decrease the waiting times across the units.

II. LITERATURE REVIEW CURRENT SYSTEMS IN PLACE

It is evidenced that the NHS uses a number of technologies to enhance the performance and organization of their work, as well as to minimize the time required for patient' management:

EMIS (Eton Medical Information Systems)
The general practitioners commonly utilize this system for record keeping, appointments, prescriptions and clinical note (Bar-Haim, Baraitser and Moore, 2023). However, it primarily functions independently and the communication and integration with different practices and hospitals is not easy.

NHS App
This is a mobile application intended to provide patient self-management services, including appointment booking, viewing health records, and requesting prescriptions. However, it does not support dynamic triage or queue management to the extent that it may be desired.

E-Referral Service (formerly Choose and Book)
This allows patients to receive hospital or specialty bookings through appointments made by their GP. It increases the construction of sub-specialties of specialists for patients but does not allow to understand if the time is expected to be wasted or resources required to be allocated.

The Summary Care Records (SCR) include the patient's basic information, allergies, medicines taken and reactions to them, and are transferable across care organizations. However, the functions fail

to provide full, live information in SCRs and sometimes need to be filled by a person.
They still fill out some of the forms manually and in so doing are prone to making some errors and thus end up duplicating some tasks (Catty, Davies and Baraitser, 2024).

Research Insights and Gaps
Both academicians and professionals in the industry have pointed to the possibilities of favorable effects of AI and digital health on the national health systems.

Machine learning was pointed out in Deloitte's report entitled "AI in Healthcare" as being able to enhance diagnosis, utilization of resources, and decisions regarding early action. But it justified own use of such technologies was relatively restricted in nationalized systems because of reasons related to regulations, and finances.

The company has, therefore, shown that it is possible to use consultation tools operated by artificial intelligence yielding quicker results in diagnosing minor illnesses. Nevertheless, as a rule their usage is limited to the private practice development and, in a number of cases, to pilot ones.

NHSX Reports: Have provided an account of how remote monitoring tools as well as digital health pathways were utilized during the COVID-19 pandemic, with possibilities of further expansion of digitization. However, these tools were used in 'firefighting' fashion, and had no long-term plans for becoming integrated into the infrastructure (van Ginneken et al., 2022).

Some international examples provide further support to the evidential argument:
Thus, the calculated results of the experiments can demonstrate an average decrease in queue waiting time by 15 per cent implemented in Canada and Sweden's E.Ds.
Singapore has introduced real time tracking of hospital beds and integrated central care plans of both the hospitals and community care (Cooke et al., 2004).

Identified Gaps:
Integrated Patient Monitoring and Record: At present, there is a severe lack of real-time gross root data sharing between the NHS Trusts and especially between emergency departments and wards.

Triage is still mostly manual: With much of triage still being manual, more time elapses before the patients get the attention of a physician.

Lack of adequate anticipation: Majority of the NHS facilities lack the ability to anticipate the number of patients that are expected to show up hence there might be a mismatch in staffing levels and available resources.

Siloed Structures: The current structure of digital infrastructure in the NHS needs a revamp and a significant number of general practices rely on system platforms that are unfit for purpose.

III. FINDINGS

Proposed Technological Solution: AIPFOS
The concept of the AIPFOS is a modular intelligent patient flow optimization system that can be implemented in Multiple facilities of the NHS, ranging from GP surgeries, emergency departments, outpatient services, and wards. There are six main components that are put together (Ede and Phillips, 2021).

AI Triage Assistant
Patients input symptoms via a mobile app or the NHS website. An algorithm accredited to clinical data and previous health records assesses a score and directs the patient to self-care, GP consultation, A&E visit, or specialist care. This can drastically decrease human mistakes and waiting time for more patients in the non-emergency triage category.

Predictive Analytics for Staffing
This is mainly through the process of using algorithms to scrutinize past data, such as peaks during some seasons, illnesses such as the flu, or local events, to determine future inflow of patients. This allows real-time changes for shift rosters and clinician staffing that can considerably improve the care quality that is offered to the patients (Adams, 2021). This ensures that more staffing is provided among staff areas to meet patients' needs.

Smart Queue Management
Through real-time processed triage data, patient location, and status of clinicians, the system automatically rearranges the appointment and

treatment schedules. This results in a flexible queuing system that reduces the time that patients spend waiting and also the time spent when no patients are being attended.

Integrated Virtual Consultations

Some of the routines can be attended to by the use of video consultation with the help of artificial intelligence. For example, minor skin conditions, prescription renewals, and follow-ups. The platform will also transition the patients to this mode whenever needed, leaving physical appointments for more urgent instances.

IoT-Powered Hospital Bed Tracker

The IoT devices mounted on the beds are for transmitting the real-time availability and turnover as well as the cleaning status of the beds per ward (Toth, 2020). They apply discharge prediction on information obtained from patient vital signs, results of tests, and recovery trends with the aim of helping address hospital overcrowding and congestion in the A&E.

Python Sample: AI Triage Model (Simplified)

```python
class SmartQueueManager:
    """
    Priority queue for ED / clinic using AI triage scores.
    Higher score + earlier arrival = higher priority.
    """

    def __init__(self) -> None:
        self._queue: List[QueueEntry] = []

    def add_patient(self,
                    patient: Patient,
                    vitals: VitalSigns,
                    chief_complaint: str,
                    triage_engine: Optional[TriageEngine] = None) -> TriageResult:
        engine = triage_engine or TriageEngine()
        triage_result = engine.assess(patient, vitals, chief_complaint)
        entry = QueueEntry(patient=patient, triage=triage_result)
        self._queue.append(entry)
        # Re-sort queue whenever a new pat (function) triage: Any
        self._queue.sort(key=lambda e: (e.triage.triage_level, -e.triage.score, e.arrival_time))
        return triage_result

    def get_next_patient(self) -> Optional[QueueEntry]:
        """
        Pop the highest-priority patient from the queue.
        """
        if not self._queue:
            return None
        return self._queue.pop(0)

    def peek_queue(self) -> List[QueueEntry]:
        """
        Return a snapshot of the current queue (no mutation).
        """
        return list(self._queue)

    def remove_patient(self, patient_id: str) -> None:
        self._queue = [e for e in self._queue if e.patient.id != patient_id]


# ============================================================
# SECTION 2: PATIENT BOOKING & SCHEDULING
# ============================================================

class AppointmentManager:
    """
    Simple in-memory booking engine.
    In production, plug this into your DB + calendar system.
    """

    def __init__(self) -> None:
        # key = clinician_id, value = list of appointments
```

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    """

    def __init__(self) -> None:
        # key = clinician_id, value = list of appointments
        self._appointments_by_clinician: Dict[str, List[Appointment]] = {}

    def _is_time_slot_free(
        self,
        clinician_id: str,
        start_time: datetime,
        end_time: datetime,
    ) -> bool:
        existing = self._appointments_by_clinician.get(clinician_id, [])
        for appt in existing:
            # Overlap check: (start < existing_end) and (end > existing_start)
            if (start_time < appt.end_time) and (end_time > appt.start_time):
                return False
        return True

    def book_appointment(
        self,
        appointment_id: str,
        patient: Patient,
        clinician_id: str,
        desired_start: datetime,
        duration_minutes: int,
        reason: str,
    ) -> Optional[Appointment]:
        end_time = desired_start + timedelta(minutes=duration_minutes)
        if not self._is_time_slot_free(clinician_id, desired_start, end_time):
            return None  # slot not available

        appt = Appointment(
            id=appointment_id,
            patient=patient,
            clinician_id=clinician_id,
            start_time=desired_start,
            end_time=end_time,
            reason=reason,
        )
        self._appointments_by_clinician.setdefault(clinician_id, []).append(appt)
        # Keep schedule sorted
        self._appointments_by_clinician[clinician_id].sort(
            key=lambda a: a.start_time
        )
        return appt
```

Overview

This is a sample of a Hospital Artificial Intelligence Management System, which is built, with the use of Python. It covers four key parts:

- The developed AI Triage system makes use of a decision tree.
- To determine the level of staffing needed, this paper aims to use a machine learning regressor.
- In the following work, the necessity for a queue will be discussed as well as its implementation using priority queue.
- Bed availability with visualization support

It just considers a small example for clarity but the same kind of entities will be present in actual hospital data sets.

AI Triage System

The first part imitates a medical triage service where patients are sorted depending on the severity of their condition.

The first dataset is created with 5 records or rows, which mention the symptoms of the patient like fever, cough, and fatigue. The second one is an output, which is the triage_level where it can be classified as A&E, GP or Self-Care.

For building and training the model, DecisionTreeClassifier of Scikit-Learn is employed.

Next, a first time patient will be entered with symptoms: fever=1, cough=1, fatigue=0 to determine which category of care they require.

It assists the doctors or systems easily determine whether a patient should be assigned to low, moderate or high risk category.

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Staffing Prediction

Relative to influenza cases, this part forecasts the Figures below shows the number of staff required in numbers. A small dataset is made up of day, flu_cases, and staff_needed.

A training is then applied using RandomForestRegressor to perceive the pattern.

Then, it determines how many staff will be required for day eleven with regards to a predicted flu occurrence of one hundred and fifteen.

Purpose: Helps the hospital plan staff ahead of time during flu outbreaks.

Queue Simulation

This part aims to make a priority list so that patients will be managed according to their priority:

Patient's priority is assigned in the following manner: priority 1 is high, priority 2 is medium, priority 3 – low.

After processing all patients, there will be a list containing the patients sorted by priorities, this is offered through Python's inbuilt library queue.PriorityQueue().

Implements the 'first come, first served' business model as pertains to the delivery of care to patients; makes sure that those with the severest conditions are treated first.

Bed Availability

Suppose there is a list consisting of 20 beds; these 20 beds are given the random numbers if occupied or available randomly. It then eliminates and displays all the beds that are available.

Implementation Plan

These strategies can in fact be implemented with the understanding that the deployment of AIPFOS shall happen in a successive manner to minimize interferences and on the basis of experiences, an optimum performance shall be realized (McIntyre and Chow, 2020). All phases will include technical assessments, human participation and performance measures.

Phase 1: Pilot Deployment

The pilot will take place in a mid-size NHS Trust such as University Hospitals of Morecambe Bay and should take six months. To begin with, the most important three modules that needs to be introduced by the pilot are the artificial intelligence triage assistant, the proactive staffing forecasting, and queue management. The objective is to evaluate compatibility with existing framework, check the correctness of the mathematical formula, and quantify the changes in the A&E's turnover and patient satisfaction

(Baraitser et al., 2024). What will be measured is the average time saved and the satisfaction rate of the users, improvement of clinicians' work schedule.

Phase 2: Feedback & Staff Training

The second phase will lay focus on post-pilot assessment and these will involve separates from the staff and from the patient. Non-numerical measurements such as the user experience, system usability, and satisfaction will be obtained together with the system performance. At this stage, working details will be given following by comprehensive training sessions for the full adoption of the system among working personnel (Macleod et al., 2020). This will entail developing different technical lectures such as the workshops, case-based learning, and problem-solving activities. Specifically, the algorithms will be adjusted by the real application experiences and edge case learning.

Phase 3: Full Rollout

All the developed AIPFOS modules will therefore be implemented in the participating Trust after testing and training have been completed. This also involves using IoT sensors for tracking equipment's such as hospital beds and using block chain technology for medical records. Relationships with technology suppliers and specialist information security suppliers will guarantee data security and stability of the system (Mbwogge et al., 2022). The roll out to regions will follow capability and propensity and will be delivered with NHS Digital, NHSX, and data guardians to uphold standardization of all systems. It also entails educating the patients in the public domain so as to get familiar with the new systems which are to be implemented for the next phase of full rollout.

Expected Benefits

Reduction in A&E and GP Wait Times: Through such smart management of queues, the throughput is expected to increase by between 20–30%.

Enhanced Resource Allocation: Human resource management illustrated high working hour's optimization through near-patient staffing which ensures that many staff members are not idle as patient traffic increases.

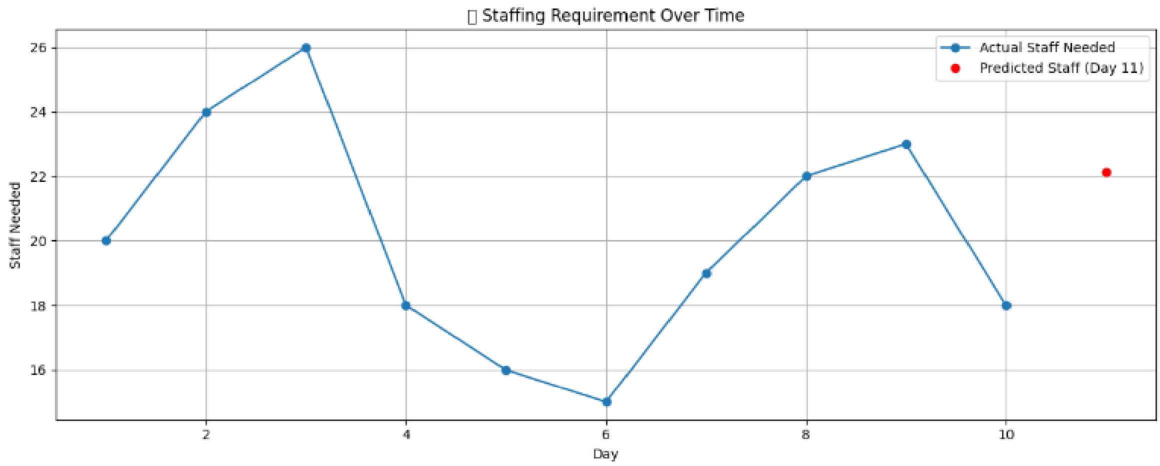

Figure no.1: Staffing Requirements Over Time

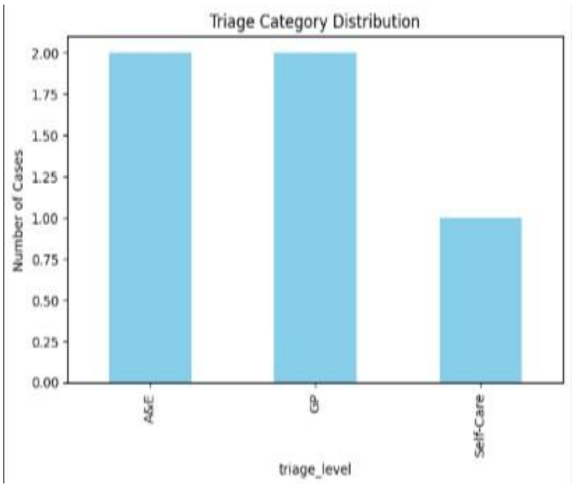

Figure no. 2: Traige Catogary Distribution

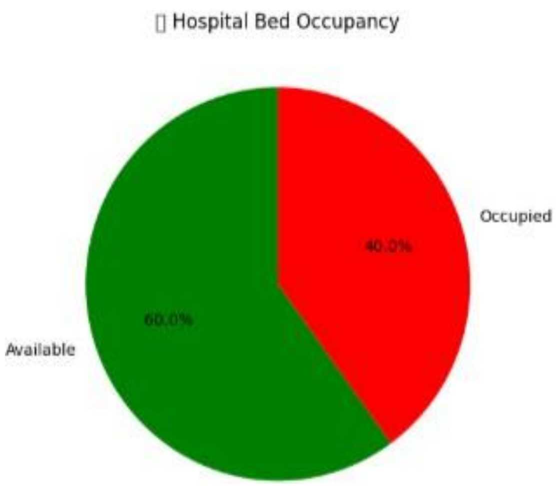

Figure no. 3: Hospital Bed Occupancy

Higher Patient Satisfaction: The commitments related to visibility on the queue, the availability of virtual channels, and faster deliveries improve people's confidence in the NHS services (Moore, 2022).

Fewer Missed Appointments: In this study, the implementation of AI, transport support, and actual real-time delay removes DNAs (Did Not Attend).
Long-Term Financial Savings: As claimed earlier, the implementation of the system would require a certain level of fixed capital investment but adequate provision of services in the cheapest alternative and thus, cut per patient costs.

IV. CONCLUSION

Improving the wait time in the NHS is not a simple process of making small modifications here and there; it is an exercise in reinvention. The use of the proposed AIPFOS framework leverages various technologies to enhance the process of patient triage, management of patient queues, and distribution of available resources as well as tracking records. This is the case because there are various unique advantages that come with adoption especially in terms of service delivery, patient and health outcomes, and overall system performance that cannot be easily dismissed by organizations implementing the change. A gradual implementation with the right supporting policies and communications to the stakeholders would make the NHS a more flexible intelligent civil service

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