University
Mohammed VI
Polytechnic

College of Computing

Deliverable 5: Views, Triggers and Application Development

Data Management Course

UM6P College of Computing

Professor: Karima Echihabi **Program:** Computer Engineering
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Contents

1 Task 1: Views and Triggers

This section details the implementation of SQL Views and Triggers for the MNHS database.

1.1 Views

1.1.1 UpcomingByHospital

Description: Returns scheduled appointment counts per hospital for the next 14 days.

```sql
CREATE VIEW UpcomingByHospital AS
SELECT
    h.Name AS HospitalName,
    ca.Date AS ApptDate,
    COUNT(*) AS ScheduledCount
FROM Appointment a
JOIN ClinicalActivity ca ON ca.CAID = a.CAID
JOIN Department d ON d.DEP_ID = ca.DEP_ID
JOIN Hospital h ON h.HID = d.HID
WHERE a.Status = 'Scheduled'
  AND ca.Date BETWEEN CURDATE() AND DATE_ADD(CURDATE(), INTERVAL
     14 DAY)
GROUP BY h.HID, h.Name, ca.Date;
```

Listing 1: UpcomingByHospital View

1.1.2 Drug Pricing Summary

Description: Summarizes average, minimum, and maximum medication prices per hospital.

```sql
CREATE VIEW DrugPricingSummary AS
SELECT
    H.HID,
    H.Name AS HospitalName,
    M.DrugID,
    M.Name AS MedicationName,
    AVG(S.Unit_Price) AS AvgUnitPrice,
    MIN(S.Unit_Price) AS MinUnitPrice,
    MAX(S.Unit_Price) AS MaxUnitPrice,
    MAX(S.StockTimestamp) AS LastStockTimestamp
FROM Stock S
JOIN Hospital H ON S.HID = H.HID
JOIN Medication M ON S.DrugID = M.DrugID
GROUP BY H.HID, H.Name, M.DrugID, M.Name;
```

Listing 2: DrugPricingSummary View

1.1.3 StaffWorkloadThirty

Description: Shows staff appointment counts (total and by status) for the last 30 days.

```sql
CREATE VIEW StaffWorkloadThirty AS
SELECT
    Staff.STAFF_ID,
    Staff.FullName,
    COUNT(Appointment.CAID) AS TotalAppointments,
    SUM(CASE WHEN Appointment.Status = 'Scheduled' THEN 1 ELSE 0
       END) AS ScheduledCount,
    SUM(CASE WHEN Appointment.Status = 'Completed' THEN 1 ELSE 0
       END) AS CompletedCount,
    SUM(CASE WHEN Appointment.Status = 'Cancelled' THEN 1 ELSE 0
       END) AS CancelledCount
FROM Staff
LEFT JOIN ClinicalActivity ON Staff.STAFF_ID = ClinicalActivity.
   STAFF_ID
    AND DATEDIFF(NOW(), ClinicalActivity.Date) < 30
LEFT JOIN Appointment ON ClinicalActivity.CAID = Appointment.CAID
GROUP BY Staff.STAFF_ID, Staff.FullName;
```

Listing 3: StaffWorkloadThirty View

1.1.4 Patient Next Visit

Description: Shows the next scheduled appointment details for each patient.

```sql
CREATE VIEW PatientNextVisit AS
SELECT
    p.IID,
    p.FullName,
    ca.Date AS NextApptDate,
    d.Name AS DepartmentName,
    h.Name AS HospitalName,
    h.City
FROM Patient p
JOIN ClinicalActivity AS ca ON ca.IID = p.IID
JOIN Appointment a ON ca.CAID = a.CAID
JOIN Department d ON ca.DEP_ID = d.DEP_ID
JOIN Hospital h ON d.HID = h.HID
WHERE a.Status = 'Scheduled'
AND ca.Date > CURDATE()
AND ca.Date = (
    SELECT MIN(ca2.Date)
    FROM ClinicalActivity AS ca2
    JOIN Appointment a2 ON ca2.CAID = a2.CAID
    WHERE ca2.IID = p.IID
    AND a2.Status = 'Scheduled'
    AND ca2.Date > CURDATE()
);
```

Listing 4: PatientNextVisit View

1.2 Triggers

1.2.1 Reject Double Booking

Description: Blocks concurrent appointments for the same staff member.

```
DELIMITER //

CREATE TRIGGER prevent_double_booking_insert
BEFORE INSERT ON Appointment
FOR EACH ROW
BEGIN
    DECLARE v_staff INT;
    DECLARE v_date DATE;
    DECLARE v_time TIME;

    SELECT STAFF_ID, Date, Time INTO v_staff, v_date, v_time
    FROM ClinicalActivity
    WHERE CAID = NEW.CAID;

    IF EXISTS (
        SELECT 1
        FROM ClinicalActivity
        WHERE STAFF_ID = v_staff
        AND Date = v_date
        AND Time = v_time
        AND CAID <> NEW.CAID
    ) THEN
        SIGNAL SQLSTATE '45000'
            SET MESSAGE_TEXT = 'Double booking detected: Staff is
                already scheduled at this time.';
    END IF;
END//

CREATE TRIGGER prevent_double_booking_update
BEFORE UPDATE ON Appointment
FOR EACH ROW
BEGIN
    DECLARE v_staff INT;
    DECLARE v_date DATE;
    DECLARE v_time TIME;

    SELECT STAFF_ID, Date, Time INTO v_staff, v_date, v_time
    FROM ClinicalActivity
    WHERE CAID = NEW.CAID;

    IF EXISTS (
        SELECT 1
        FROM ClinicalActivity
        WHERE STAFF_ID = v_staff
        AND Date = v_date
        AND Time = v_time
        AND CAID <> NEW.CAID
```

```
    ) THEN
        SIGNAL SQLSTATE '45000'
            SET MESSAGE_TEXT = 'Double booking detected: Staff is
                already scheduled at this time.';
    END IF;
END//

DELIMITER ;
```

Listing 5: Double Booking Prevention Triggers

1.2.2 Recompute Expense Total

Description: Updates expense totals upon prescription changes; blocks if prices are missing.

```
DELIMITER //

CREATE PROCEDURE RecomputeExpenseTotal(IN p_prescription_id INT)
BEGIN
    DECLARE hosp_id INT;
    DECLARE new_total DECIMAL(10,2);
    DECLARE missing_price INT DEFAULT 0;

    SELECT h.HID INTO hosp_id
    FROM Prescription p
    JOIN ClinicalActivity ca ON p.CAID = ca.CAID
    JOIN Department d ON ca.DEP_ID = d.DEP_ID
    JOIN Hospital h ON d.HID = h.HID
    WHERE p.PID = p_prescription_id;

    SELECT COUNT(*) INTO missing_price
    FROM Include i
    LEFT JOIN Stock s ON i.DrugID = s.DrugID AND s.HID = hosp_id
    WHERE i.PID = p_prescription_id AND s.Unit_Price IS NULL;

    IF missing_price > 0 THEN
        SIGNAL SQLSTATE '45000'
        SET MESSAGE_TEXT = 'Cannot compute expense: missing unit
            price for one or more medications';
    ELSE
        SELECT COALESCE(SUM(s.Unit_Price), 0) INTO new_total
        FROM Include i
        JOIN Stock s ON i.DrugID = s.DrugID AND s.HID = hosp_id
        WHERE i.PID = p_prescription_id;

        UPDATE Expense e
        JOIN Prescription p ON e.CAID = p.CAID
        SET e.Total = new_total
        WHERE p.PID = p_prescription_id;
    END IF;
END//
```

```
36
37 CREATE TRIGGER RecomputeExpenseAfterInsert
38 AFTER INSERT ON Include
39 FOR EACH ROW
40 BEGIN
41     CALL RecomputeExpenseTotal(NEW.PID);
42 END//
43
44 CREATE TRIGGER RecomputeExpenseAfterUpdate
45 AFTER UPDATE ON Include
46 FOR EACH ROW
47 BEGIN
48     CALL RecomputeExpenseTotal(NEW.PID);
49 END//
50
51 CREATE TRIGGER RecomputeExpenseAfterDelete
52 AFTER DELETE ON Include
53 FOR EACH ROW
54 BEGIN
55     CALL RecomputeExpenseTotal(OLD.PID);
56 END//
57
58 DELIMITER ;
```

Listing 6: Expense Recalculation Triggers

1.2.3 Prevent Negative or Inconsistent Stock

Description: Enforces positive prices and prevents negative stock quantities.

```
1  DELIMITER //
2
3  CREATE TRIGGER PreventInvalidStock
4  BEFORE INSERT ON Stock
5  FOR EACH ROW
6  BEGIN
7      IF NEW.Qty < 0 THEN
8          SIGNAL SQLSTATE '45000'
9          SET MESSAGE_TEXT = 'ERROR: Quantity cannot be negative.';
10     END IF;
11
12     IF NEW.Unit_Price <= 0 THEN
13         SIGNAL SQLSTATE '45000'
14         SET MESSAGE_TEXT = 'ERROR: Unit price must be positive.';
15     END IF;
16
17     IF NEW.ReorderLevel < 0 THEN
18         SIGNAL SQLSTATE '45000'
19         SET MESSAGE_TEXT = 'ERROR: Reorder level cannot be
               negative.';
20     END IF;
21 END//
```

```sql

CREATE TRIGGER PreventInvalidStockUpdate
BEFORE UPDATE ON Stock
FOR EACH ROW
BEGIN
    IF NEW.Qty < 0 THEN
        SIGNAL SQLSTATE '45000'
        SET MESSAGE_TEXT = 'ERROR: Quantity cannot be negative.';
    END IF;

    IF NEW.Unit_Price <= 0 THEN
        SIGNAL SQLSTATE '45000'
        SET MESSAGE_TEXT = 'ERROR: Unit price must be positive.';
    END IF;

    IF NEW.ReorderLevel < 0 THEN
        SIGNAL SQLSTATE '45000'
        SET MESSAGE_TEXT = 'ERROR: Reorder level cannot be
           negative.';
    END IF;

    IF NEW.Qty < OLD.Qty AND NEW.Qty < 0 THEN
        SIGNAL SQLSTATE '45000'
        SET MESSAGE_TEXT = 'ERROR: Cannot decrease quantity below
            zero.';
    END IF;
END//

DELIMITER ;
```

Listing 7: Stock Validation Triggers

1.2.4 Protect Referential Integrity on Patient Delete

Description: Prevents deleting patients who have existing clinical activities.

```sql
DELIMITER //

CREATE TRIGGER PreventPatientDelete
BEFORE DELETE ON Patient
FOR EACH ROW
BEGIN
    IF EXISTS (
        SELECT IID FROM ClinicalActivity ca
        WHERE ca.IID = OLD.IID
    ) THEN
        SIGNAL SQLSTATE '45000'
        SET MESSAGE_TEXT = 'Cannot delete patient. Please
           reassign or delete dependent clinical activities first
           .';
    END IF;
END//
```

```
15
16 DELIMITER ;
```

Listing 8: Patient Delete Protection Trigger

2 Task 2: Application Layer for MNHS Database

2.1 Summary

The primary objective of this project is to develop a secure and user-friendly "Application Layer" for the MNHS database.The project prioritizes architectural robustness through the implementation of security best practices, including parameterized queries and environment-based credential management.

2.2 Technical Stack

2.2.1 The Frontend: Streamlit

The application interface is built using **Streamlit**, a Python-based framework designed for the rapid development of data-driven web applications. Streamlit abstracts the frontend complexity (HTML/CSS/JavaScript), allowing for a direct integration of the Python application logic with the user interface.

In this implementation, Streamlit serves three critical functions:

- **Navigation Control:** `st.sidebar` is utilized to create a modular navigation menu, separating distinct business functions (e.g., Patient Directory, Scheduling, Analytics) into isolated views.

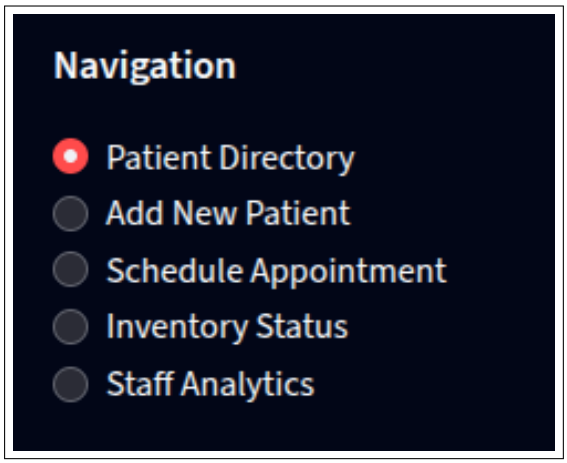


Figure 1: Navigation Menu

```
        st.sidebar.markdown("###
            Navigation")
        menu_options = [
        "Patient Directory",
        "Add New Patient",
        "Schedule Appointment",
        "Inventory Status",
        "Staff Analytics"
        ]
        choice = st.sidebar.
           radio("Go to",
           menu_options,
           label_visibility="
           collapsed")
```

Listing 9: Python code for sidebar/navigation

- **Input Handling:** `st.form` and `st.form_submit_button` are employed to batch user inputs. This prevents premature database queries by ensuring that transactional data (such as appointment details) is only sent to the backend upon explicit user confirmation.

```
    with st.form("appt_form"):
            st.markdown("#### Appointment Details")
            c1, c2, c3 = st.columns(3)
            with c1:
```

```
                st.text_input("New Activity ID (Auto)", value
                    =next_caid, disabled=True)
            with c2:
                date = st.date_input("Date")
            with c3:
                time = st.time_input("Time")

            reason = st.text_area("Reason for visit", height
                =100)
            submitted = st.form_submit_button("Confirm
                Schedule", type="primary", use_container_width
                =True)
```

Listing 10: Python code for the form in the schedule appointment section

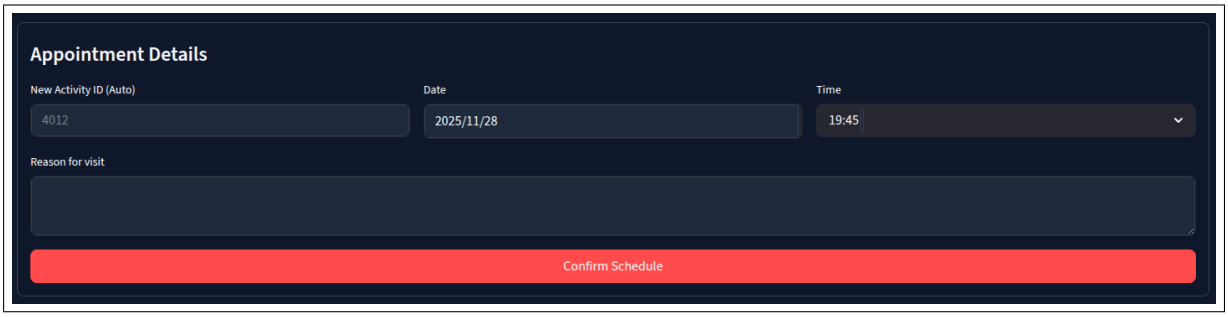
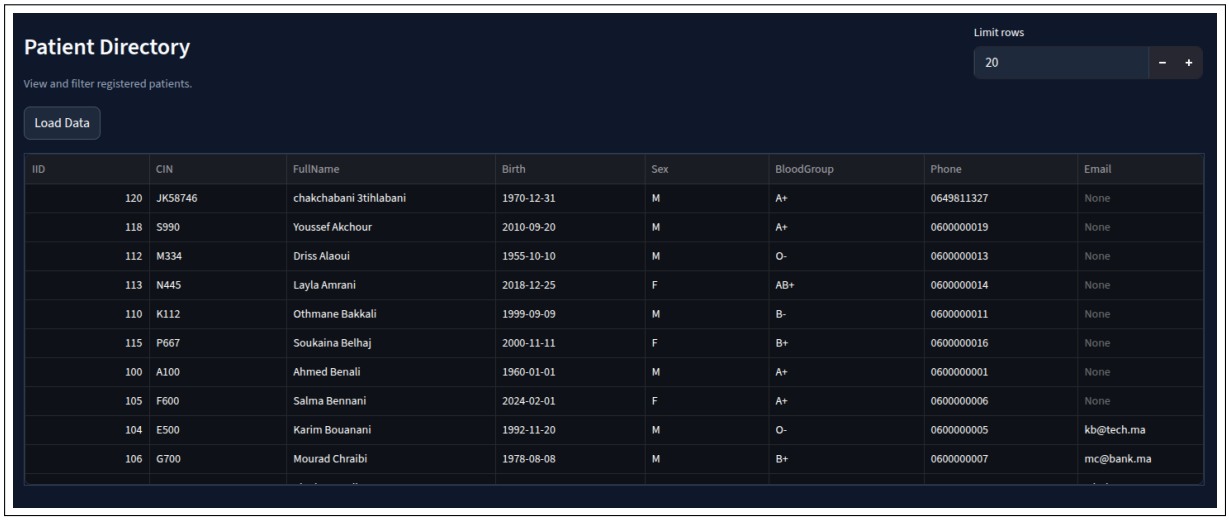


Figure 2: Appointment Form

- **Data Visualization:** The framework native integration with **Pandas** allows for the direct rendering of SQL query results into interactive tables (`st.dataframe`) and charts.

```
    if st.button("Load Data"):
            with st.spinner("Fetching..."):
                results = list_patients_ordered_by_last_name(
                    limit)
                if results:
                    df = pd.DataFrame(results)
                    st.dataframe(df, use_container_width=True
                        , hide_index=True)
                else:
                    st.info("No records found.")
```

Listing 11: Python code for the rendering of the patients table using st.dataframe



IID	CIN	FullName	Birth	Sex	BloodGroup	Phone	Email
120	JK58746	chakchabani 3tihlabani	1970-12-31	M	A+	0649811327	None
118	S990	Youssef Akchour	2010-09-20	M	A+	0600000019	None
112	M334	Driss Alaoui	1955-10-10	M	O-	0600000013	None
113	N445	Layla Amrani	2018-12-25	F	AB+	0600000014	None
110	K112	Othmane Bakkali	1999-09-09	M	B-	0600000011	None
115	P667	Soukaina Belhaj	2000-11-11	F	B+	0600000016	None
100	A100	Ahmed Benali	1960-01-01	M	A+	0600000001	None
105	F600	Salma Bennani	2024-02-01	F	A+	0600000006	None
104	E500	Karim Bouanani	1992-11-20	M	O-	0600000005	kb@tech.ma
106	G700	Mourad Chraibi	1978-08-08	M	B+	0600000007	mc@bank.ma

Figure 3: Patients Table

2.2.2 The Backend: TiDB

The application backend relies on **TiDB**, an open-source distributed SQL database.

Implementation Logic:

- **Protocol:** The application interacts with TiDB exactly like a standard single-node MySQL instance. The `mysql-connector-python` library is used to manage the connection, requiring no specialized TiDB-specific client code.
- **Secure Connection:** To maintain security best practices, the connection logic is encapsulated in a helper function. This function reads sensitive credentials (Host, Port, User, Password) dynamically from environment variables (`.env`) rather than hard-coding them, ensuring the distributed cluster is accessed securely.

```
# Local .env configuration
def get_connection():
    """
    Establishes a database connection with a hybrid approach:
    1. Tries to load from Streamlit Secrets (st.secrets) for
       Cloud deployment.
    2. Falls back to local .env file using python-dotenv for
       local dev.
    """
    try:
        # Attempt to access Streamlit Secrets
        # This will work if .streamlit/secrets.toml exists or on
           Streamlit Cloud
        return mysql.connector.connect(
            host=st.secrets["mysql"]["host"],
            port=st.secrets["mysql"]["port"],
            database=st.secrets["mysql"]["database"],
            user=st.secrets["mysql"]["user"],
            password=st.secrets["mysql"]["password"]
        )
```

```
    except (FileNotFoundError, KeyError):
        # Fallback: Load environment variables from .env file
        load_dotenv()

        # Ensure port is an integer
        port_val = os.getenv("MYSQL_PORT", 3306)

        return mysql.connector.connect(
            host=os.getenv("MYSQL_HOST"),
            port=int(port_val),
            database=os.getenv("MYSQL_DB"),
            user=os.getenv("MYSQL_USER"),
            password=os.getenv("MYSQL_PASSWORD")
        )
```

Listing 12: TiDB Connection Implementation

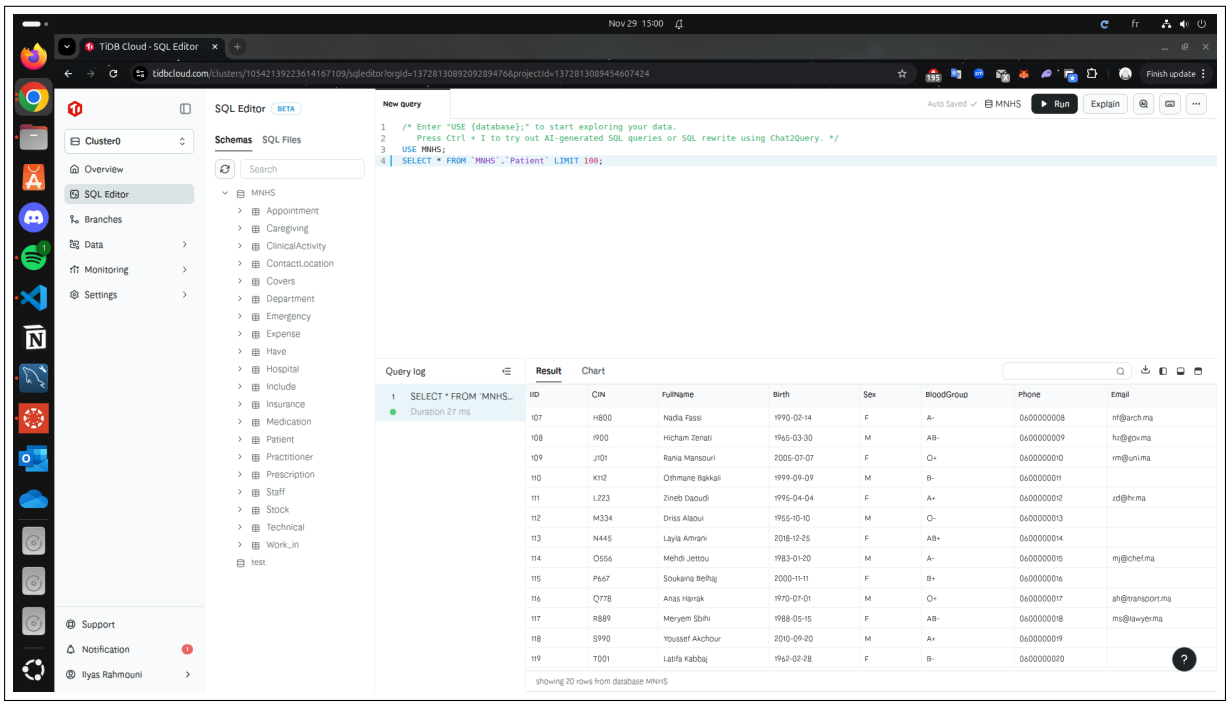


Figure 4: TiDB SQL Editor

2.3 Implementation Code Logic

2.3.1 Module 1: Patient Directory (list_patients)

The Patient Directory module provides the user with a searchable, ordered view of registered patients. The lab specifically asks for the first 20 patients, this is set as the default value for the limit rows option. But we took the liberty to add the possibility of choosing the number of rows to show as an option.

2.3.1.1 UI Implementation: Server-Side Pagination To ensure optimal performance, the application avoids fetching the entire dataset at once. Instead, it implements a "Server-Side Pagination" strategy controlled by the user.

- **Dynamic Limit Control:** A Streamlit number input (`st.number_input`) allows the user to specify exactly how many records to retrieve (e.g., 10, 20, 50).

```
1     limit = st.number_input("Limit rows", 5, 100, 20)
```

Listing 13: Python code for the limit choice

Figure 5: Dynamic Limit Control

- **Performance Impact:** This input is passed directly to the SQL `LIMIT` clause. This ensures that the heavy lifting is done by the database engine (TiDB), and only the requested subset of data is transmitted over the network to the Python frontend.

```
1     if st.button("Load Data"):
2             with st.spinner("Fetching..."):
3                 results = list_patients_ordered_by_last_name(
                      limit)
```

Listing 14: Python code calling the function list patients ordered by last name at the press of Load Data button with the limit as an argument to the function

2.3.1.2 SQL Logic: String Manipulation for Sorting A task to implement for this application layer was to order patients by their **Last Name**. However, the database schema provided stores the name as a single string in the `FullName` column (e.g., "Ahmed Benali").

Standard SQL sorting (`ORDER BY FullName`) would incorrectly sort by the first name. To resolve this without altering the schema, the application utilizes the `SUBSTRING_INDEX` function.

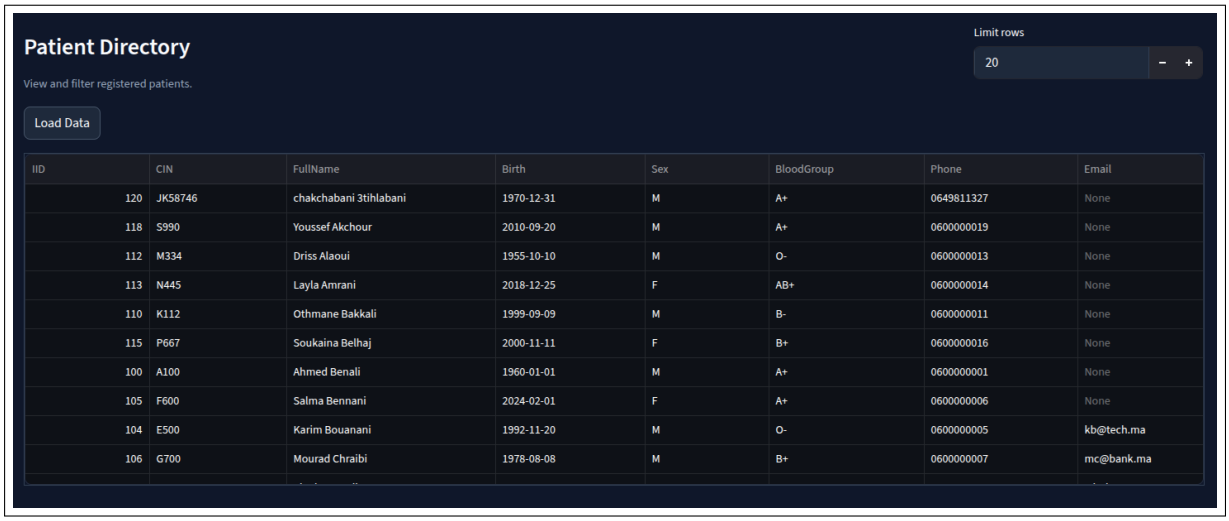
The Sorting Algorithm:

1. The query isolates the string segment occurring after the last space character using `SUBSTRING_INDEX(FullName, ' ', -1)`.

2. This extracted token (the surname) is used as the primary sort key.
3. The full name is used as a secondary sort key to resolve ties.

```python
def list_patients_ordered_by_last_name(limit=20):
    sql = """
    SELECT IID, CIN, FullName, Birth, Sex, BloodGroup, Phone,
       Email
    FROM Patient
    ORDER BY SUBSTRING_INDEX(FullName, ' ', -1)
    LIMIT %s
    """
    try:
        with get_connection() as cnx:
            with cnx.cursor(dictionary=True) as cur:
                cur.execute(sql, (limit,))
                return cur.fetchall()
    except Exception as e:
        st.error(f"Error fetching patients: {e}")
        return []
```

Listing 15: Python code including SQL Query for Surname Sorting



IID	CIN	FullName	Birth	Sex	BloodGroup	Phone	Email
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106	G700	Mourad Chraibi	1978-08-08	M	B+	0600000007	mc@bank.ma

Figure 6: Patients Table Output

2.3.2 Module 2: Intelligent Scheduling System (schedule_appt)

The implementation of this module/functionality prioritizes user experience by abstraction the actual complex data base identifiers and automating the CAID choice.

2.3.2.1 User-Friendly Input Abstraction A key usability challenge in database applications is that end-users (medical staff) do not know internal Primary Keys (e.g., that "Dr. Leila" is `STAFF_ID=2` or "Cardiology" is `DEP_ID=11`).

To resolve this, the application implements a **Translation Layer** using Streamlit and Python dictionaries:

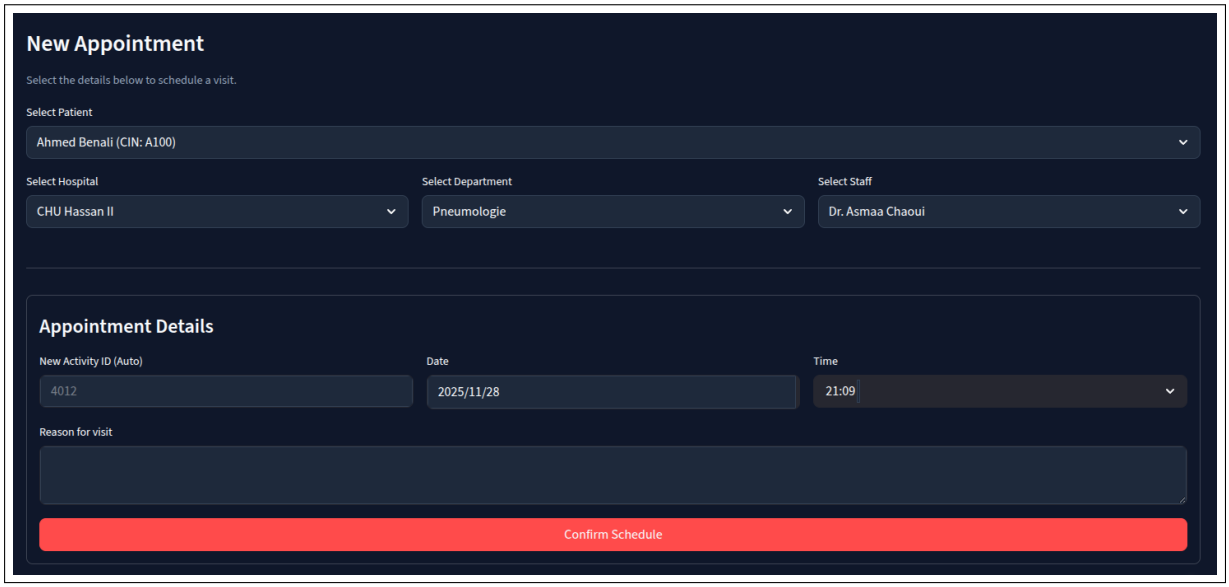


Figure 7: User-Friendly interface

1. **Fetching:** On page load, the application executes `SELECT` queries to retrieve human-readable names (Staff Full Name, Hospital Name, Department Name).

```
    all_patients = get_all_patients()
    all_hospitals = get_all_hospitals()
    all_staff = get_all_staff()
```

Listing 16: Python code for fetching process on page load

2. **Mapping:** These results are stored in a Python dictionary mapping the Name (Key) to the ID (Value) as seen above.

```
    patient_options = {f"{p['FullName']} (CIN: {p['CIN']})":
       p['IID'] for p in all_patients}
    # patient_options is the dictionary in question
    # it contains patient names and cin as keys and iids as
       values
```

Listing 17: Python code for patients dictionnary as an example

3. **Selection:** The user interacts with a `st.selectbox` displaying only the names.

```
    selected_patient_label = st.selectbox("Select Patient",
       options=list(patient_options.keys()))
```

Listing 18: Python code for selection

4. **Translation:** Upon submission, the application looks up the corresponding ID from the dictionary to use in the SQL `INSERT` statement.

```
    selected_iid = patient_options[selected_patient_label]
```

Listing 19: Python code for iid lookup

2.3.2.2 Automated ID Generation To prevent "Duplicate Key" errors and reduce manual entry, the application automatically calculates the next available Clinical Activity ID (`CAID`).

Logic: Before the transaction begins, the application queries the maximum existing ID in the `ClinicalActivity` table. The new ID is calculated as $MAX(CAID) + 1$.

```
    def get_next_caid():
        sql = "SELECT MAX(CAID) as max_id FROM ClinicalActivity"
        try:
            with get_connection() as cnx:
                with cnx.cursor(dictionary=True) as cur:
                    cur.execute(sql)
                    res = cur.fetchone()
                    if res and res['max_id']:
                        return res['max_id'] + 1
                    return 1000
        except: return 1000
```

Listing 20: Next CAID Calculation helper function

```
    next_caid = get_next_caid()
```

Listing 21: Function call at page load

2.3.2.3 Transactional Integrity The scheduling process involves two distinct SQL write operations:

1. Creating the parent event in the `ClinicalActivity` table.
2. Creating the specific status in the `Appointment` table.

To ensure data consistency, if the second insert fails (e.g., due to a constraint violation), the first insert is automatically reversed (`ROLLBACK`)

```
if submitted:
    if selected_dep_id is None:
        st.error("Invalid Department.")
    else:
        try:
```

```
            schedule_appointment(next_caid, selected_iid,
                selected_staff_id, selected_dep_id, str(date), str
                (time), reason)
                        st.success(f"Appointment scheduled (ID: {
                            next_caid})")
        except Exception as e:
            st.error(f"Failed to schedule: {e}")
```

Listing 22: schedule_appointment function call at the press of Confirme Schedule button

```
def schedule_appointment(caid, iid, staff_id, dep_id, date_str,
    time_str, reason):
    """
    Schedules an appointment with 'Double Booking' protection.
    """
    # 1. Validation SQL: Check if staff is already booked
    check_sql = """
    SELECT CAID
    FROM ClinicalActivity
    WHERE STAFF_ID = %s AND Date = %s AND Time = %s
    LIMIT 1
    """
    ins_ca = """
    INSERT INTO ClinicalActivity (CAID, IID, STAFF_ID, DEP_ID,
        Date, Time)
    VALUES (%s, %s, %s, %s, %s, %s)
    """
    ins_appt = """
    INSERT INTO Appointment (CAID, Reason, Status)
    VALUES (%s, %s, 'Scheduled')
    """
    with get_connection() as cnx:
        try:
            with cnx.cursor() as cur:
                # --- [TRIGGER LOGIC START] ---
                # Check for double booking before doing anything
                cur.execute(check_sql, (staff_id, date_str,
                    time_str))
                conflict = cur.fetchone()
                if conflict:
                    # STOP! Raise an error to prevent the insert
                    raise ValueError(f"Double Booking Error:
                        Staff {staff_id} is already busy at {
                        time_str} on {date_str}.")
                # --- [TRIGGER LOGIC END] ---
                # If no conflict, proceed with the transaction
                cur.execute(ins_ca, (caid, iid, staff_id, dep_id,
                    date_str, time_str))
                cur.execute(ins_appt, (caid, reason))
                cnx.commit()
                return True
        except Exception as e:
```

```
37                cnx.rollback()
38                raise e
```

Listing 23: schedule_appointment function

2.3.2.4 Note on Architectural Adaptation The final implementation of this scheduling module includes specific validation logic to enforce the "Double Booking" constraint. However, due to the architectural differences between standard MySQL and the distributed TiDB backend, specifically the lack of support for `CREATE TRIGGER`, this validation was strategically shifted from the database layer to the application layer. A detailed technical justification for this design choice is presented in 2.4 Adaptation Strategy

2.3.3 Module 3: Inventory & Low Stock (low_stock)

This module detects only low quantity medication stocks including also medications with no stock at all. Unlike a standard data retrieval, this functionality utilizes various techniques to filter and load only the wanted rows in the specified format.

2.3.3.1 SQL Query Explanation: A standard SQL query on the `Stock` table can easily find items where `Qty < ReorderLevel`. However, if a hospital has completely run out of a medication, or never logged it, there may be **no row at all** in the `Stock` table for that specific Hospital-Drug combination.

To solve this, the application implements a **Cross-Join Strategy**:

1. **Cartesian Product:** A `CROSS JOIN` is performed between the `Hospital` table and the `Medication` table. This generates a theoretical matrix of every possible medication in every hospital.

```
    FROM Medication M
    CROSS JOIN Hospital H
```

Listing 24: Cross-Join Logic for Missing Stock

2. **Left Join:** The application then `LEFT JOIN`s the actual `Stock` table against this matrix.

```
    LEFT JOIN Stock S ON M.DrugID = S.DrugID AND H.HID = S.
       HID
```

Listing 25: Left Join the actual Stock Table

3. **Null Handling:** If no stock record matches, the database returns `NULL`. The query uses `COALESCE(Qty, 0)` to interpret this `NULL` as a quantity of zero, triggering the alert.

```
    COALESCE(S.Qty, 0) AS CurrentQuantity,
    COALESCE(S.ReorderLevel, 0) AS ReorderLevel,
```

Listing 26: COALESCE Function

4. **COALESCE Function:** The `COALESCE` function safeguards the query logic by converting any `NULL` values, resulting from missing inventory records, into a computational zero, ensuring that complete stockouts are accurately identified and flagged.

```
    SELECT
    M.Name AS MedicationName,
    H.Name AS HospitalName,
    COALESCE(S.Qty, 0) AS CurrentQuantity,
    COALESCE(S.ReorderLevel, 0) AS ReorderLevel,
    CASE
        WHEN S.Qty IS NULL THEN 'No Stock'
        WHEN S.Qty < S.ReorderLevel THEN 'Low Stock'
        ELSE 'Adequate'
    END AS StockStatus
```

```
    FROM Medication M
    CROSS JOIN Hospital H
    LEFT JOIN Stock S ON M.DrugID = S.DrugID AND H.HID = S.HID
    WHERE S.Qty IS NULL OR S.Qty < S.ReorderLevel
    ORDER BY M.Name, H.Name;
```

Listing 27: Full Sql Query

2.3.3.2 UI Implementation — Visual Alerting : To make this data actionable for administrators, the application avoids displaying a raw wall of text. Instead, it utilizes **Pandas Styling** to apply conditional formatting to the data before rendering it in Streamlit.

Logic: A Python function iterates through the result set:

- **Red Highlight:** Applied if the status is "No Stock" (Qty = 0).
- **Orange Highlight:** Applied if the status is "Low Stock" (0 ¡ Qty ¡ ReorderLevel).

```
    def style_status(val):
        color = '#ef4444' if val == 'No Stock' else '#f59e0b'
            if val == 'Low Stock' else '#94A3B8'
        return f'color: {color}; font-weight: 500'
```

Listing 28: Python Function used for the styling

2.3.3.3 UI Implementation — Donut Chart : To provide an immediate assessment of the hospital's overall inventory health, the interface includes a summary Donut Chart built using **Plotly Express**.

Code Logic:

1. **Aggregation:** The application aggregates the SQL results using `value_counts()` on the 'StockStatus' column to determine the distribution of critical vs. adequate stock.

```
status_counts = df['StockStatus'].value_counts()
```

Listing 29: value_counts() function on the StockStatus

2. **Visualization:** A pie chart with a center hole (`hole=0.6`) is generated to create a modern "Donut" aesthetic.
3. **Semantic Coloring:** To ensure consistency with the table highlights, the chart utilizes a specific color sequence: Red (`#ef4444`) for shortages, Orange (`#f59e0b`) for low stock, and Grey for adequate items.

Figure 8: Low Stock Interface

```
# Create a Donut chart with semantic colors
fig = px.pie(
    values=status_counts.values,
    names=status_counts.index,
    hole=0.6, # Creates the donut shape
    # Red for Critical, Orange for Warning
    color_discrete_sequence=['#ef4444', '#f59e0b', '#475569'],
    template="plotly_dark"
)
st.plotly_chart(fig, use_container_width=True)
```

Listing 30: Plotly Donut Chart Configuration

2.3.4 Module 4: Staff Workload Analytics (staff_share)

This module provides the user with performance metrics, calculating the share of appointments handled by each staff member relative to their specific hospital's total workload. This requires an SQL aggregation and a visualization strategy capable of handling multi-hospital employment.

2.3.4.1 SQL Logic: Calculating a percentage share requires: the count for the individual staff member and the total count for the hospital. We will use Subqueries to achieve the desired result (Nested Subqueries).

The Query Structure:

1. **Subquery S (Staff):** Counts appointments grouped by `STAFF_ID` and `HID`. This yields the numerator (Individual Workload).

```
    SELECT ca.STAFF_ID, st.FullName, dep.HID, COUNT(a.CAID)
       AS StaffApp
    FROM Appointment a
    JOIN ClinicalActivity ca ON a.CAID = ca.CAID
    JOIN Staff st ON ca.STAFF_ID = st.STAFF_ID
    JOIN Department dep ON ca.DEP_ID = dep.DEP_ID
    GROUP BY ca.STAFF_ID, st.FullName, dep.HID
```

Listing 31: Staff Subquery

2. **Subquery H (Hospital):** Counts appointments grouped by `HID` only. This yields the denominator (Hospital Total).

```
    SELECT dep.HID, Hosp.Name, COUNT(a.CAID) AS HospitalApp
    FROM Appointment a
    JOIN ClinicalActivity ca ON ca.CAID = a.CAID
    JOIN Department dep ON ca.DEP_ID = dep.DEP_ID
    JOIN Hospital Hosp ON dep.HID = Hosp.HID
    GROUP BY dep.HID, Hosp.Name
```

Listing 32: Hospital Subquery

3. **Main Query:** Joins these two virtual tables on `HID` to calculate the percentage: $\frac{\text{Staff Appts}}{\text{Hospital Appts}} \times 100$.

```
    SELECT
    s.STAFF_ID,
    s.FullName AS StaffName,
    h.Name AS HospitalName,
    s.StaffApp AS TotalAppointments,
    ROUND((s.StaffApp / h.HospitalApp) * 100, 2) AS
       PercentageShare
    FROM (
        SELECT ca.STAFF_ID, st.FullName, dep.HID, COUNT(a.CAID)
           AS StaffApp
        FROM Appointment a
        JOIN ClinicalActivity ca ON a.CAID = ca.CAID
```

```
        JOIN Staff st ON ca.STAFF_ID = st.STAFF_ID
        JOIN Department dep ON ca.DEP_ID = dep.DEP_ID
        GROUP BY ca.STAFF_ID, st.FullName, dep.HID
    ) s
    JOIN (
        SELECT dep.HID, Hosp.Name, COUNT(a.CAID) AS HospitalApp
        FROM Appointment a
        JOIN ClinicalActivity ca ON ca.CAID = a.CAID
        JOIN Department dep ON ca.DEP_ID = dep.DEP_ID
        JOIN Hospital Hosp ON dep.HID = Hosp.HID
        GROUP BY dep.HID, Hosp.Name
    ) h ON s.HID = h.HID
    ORDER BY h.HID, PercentageShare DESC;
```

Listing 33: Full Query for appointment share

2.3.4.2 UI Implementation — Bar Chart A significant challenge in visualizing this data is that many doctors work across multiple hospital sites. Using a standard bar chart often results in data points for the same doctor overlapping illegibly.

The Solution: To resolve this, the application utilizes the **Plotly Express** library to render a **Horizontal Grouped Bar Chart**. This approach offers superior clarity over standard charts through three key mechanisms:

- **Grouped Mode (`barmode='group'`):** Instead of stacking values, this setting forces the chart to place bars side-by-side for the same staff member. If a doctor works in "Casablanca" and "Rabat," they appear as two distinct, adjacent bars, preventing any visual overlap.
- **Semantic Coloring:** The `HospitalName` is mapped to a discrete color sequence. This allows users to visually distinguish which hospital contributes to the specific workload share at a glance.
- **Horizontal Orientation:** Given that staff names can be long, setting `orientation='h'` ensures all labels are readable without rotation or truncation.

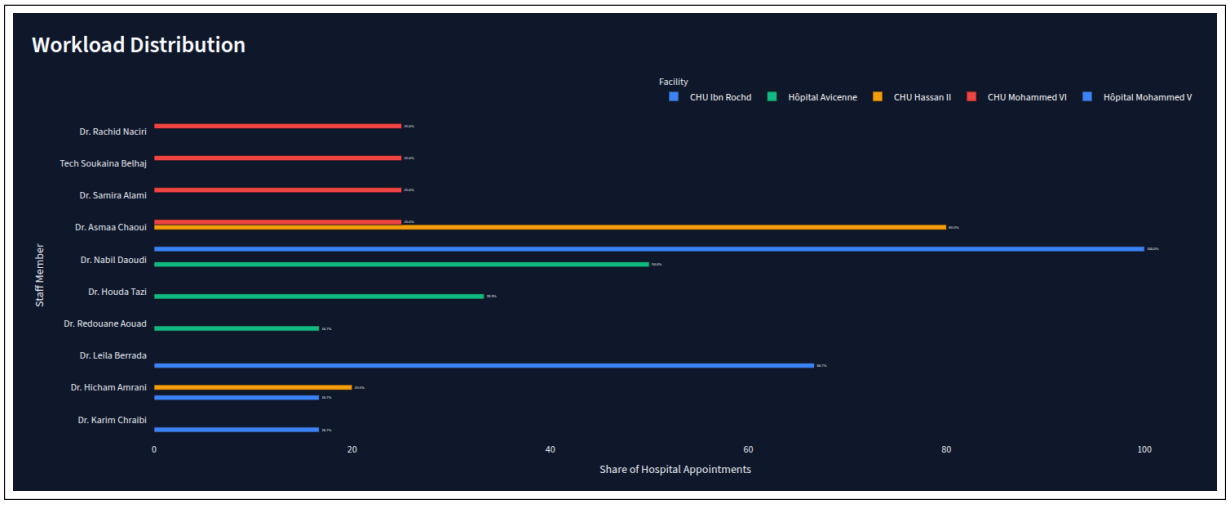


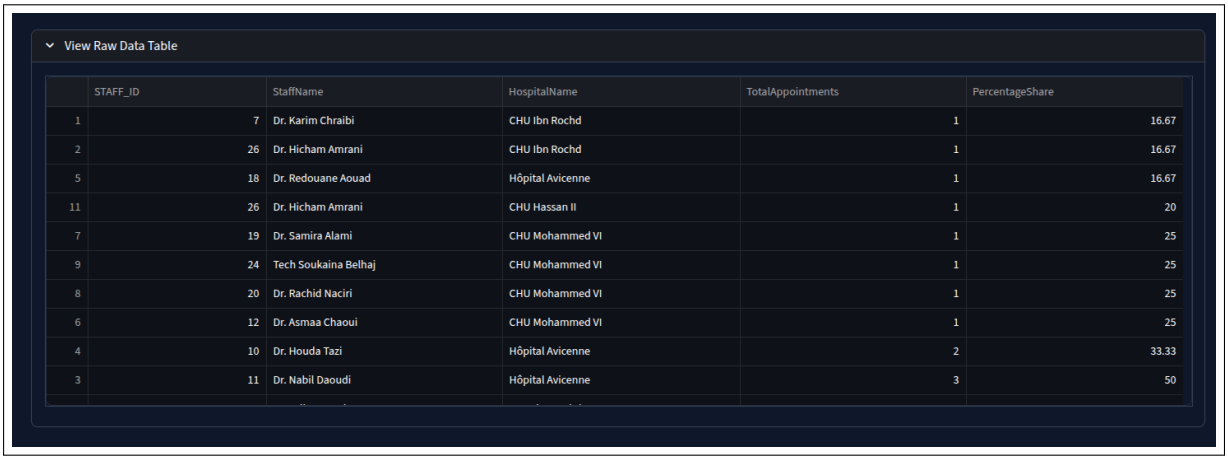
Figure 9: BarChart Final Result

```python
# Using Plotly Express to handle multi-site overlaps
# Using px.bar with barmode='group' prevents overlapping.
fig = px.bar(
    df,
    x="PercentageShare",
    y="StaffName",
    color="HospitalName",
    orientation='h',
    barmode='group',
    text="PercentageShare",
    color_discrete_sequence=['#3b82f6', '#10b981', '#f59e0b', '#ef4444', "#b3ff00"],
    labels={"PercentageShare": "Share (%)", "StaffName": "Staff Member", "HospitalName": "Facility"}
)

fig.update_traces(texttemplate='%{text:.1f}%', textposition='outside')
fig.update_layout(
    title="",
    xaxis_title="Share of Hospital Appointments",
    template="plotly_dark",
    height=500,
    margin=dict(l=0, r=0, t=0, b=0),
    paper_bgcolor='rgba(0,0,0,0)',
    plot_bgcolor='rgba(0,0,0,0)',
    font=dict(color='#F8FAFC'),
    xaxis=dict(showgrid=False),
    yaxis=dict(showgrid=False),
    legend=dict(orientation="h", yanchor="bottom", y=1.02, xanchor="right", x=1)
)

st.plotly_chart(fig, use_container_width=True)
```

Listing 34: Plotly Grouped Bar Chart Logic



	STAFF_ID	StaffName	HospitalName	TotalAppointments	PercentageShare
1	7	Dr. Karim Chraibi	CHU Ibn Rochd	1	16.67
2	26	Dr. Hicham Amrani	CHU Ibn Rochd	1	16.67
5	18	Dr. Redouane Aouad	Hôpital Avicenne	1	16.67
11	26	Dr. Hicham Amrani	CHU Hassan II	1	20
7	19	Dr. Samira Alami	CHU Mohammed VI	1	25
9	24	Tech Soukaina Belhaj	CHU Mohammed VI	1	25
8	20	Dr. Rachid Naciri	CHU Mohammed VI	1	25
6	12	Dr. Asmaa Chaoui	CHU Mohammed VI	1	25
4	10	Dr. Houda Tazi	Hôpital Avicenne	2	33.33
3	11	Dr. Nabil Daoudi	Hôpital Avicenne	3	50

Figure 10: Raw Data Table

2.3.5 Module 5: Patient Registration Utility (add_new_patient)

2.3.5.1 Context This module was not part of the original lab specifications. It was integrated into the final application following a recommendation from our Teaching Assistant, Miss Guerbouzi. We determined that a dedicated interface for registering new patients would serve as an invaluable tool for population and debugging, allowing us to rapidly generate test cases for the other modules.

2.3.5.2 Implementation Overview From a technical perspective, the architecture of this module is similar to the **Intelligent Scheduling System** (Module 2). It employs a similar strategy of form-based input handling and parameterized SQL insertion. To avoid redundancy, the functional logic of this module is not detailed in this document.

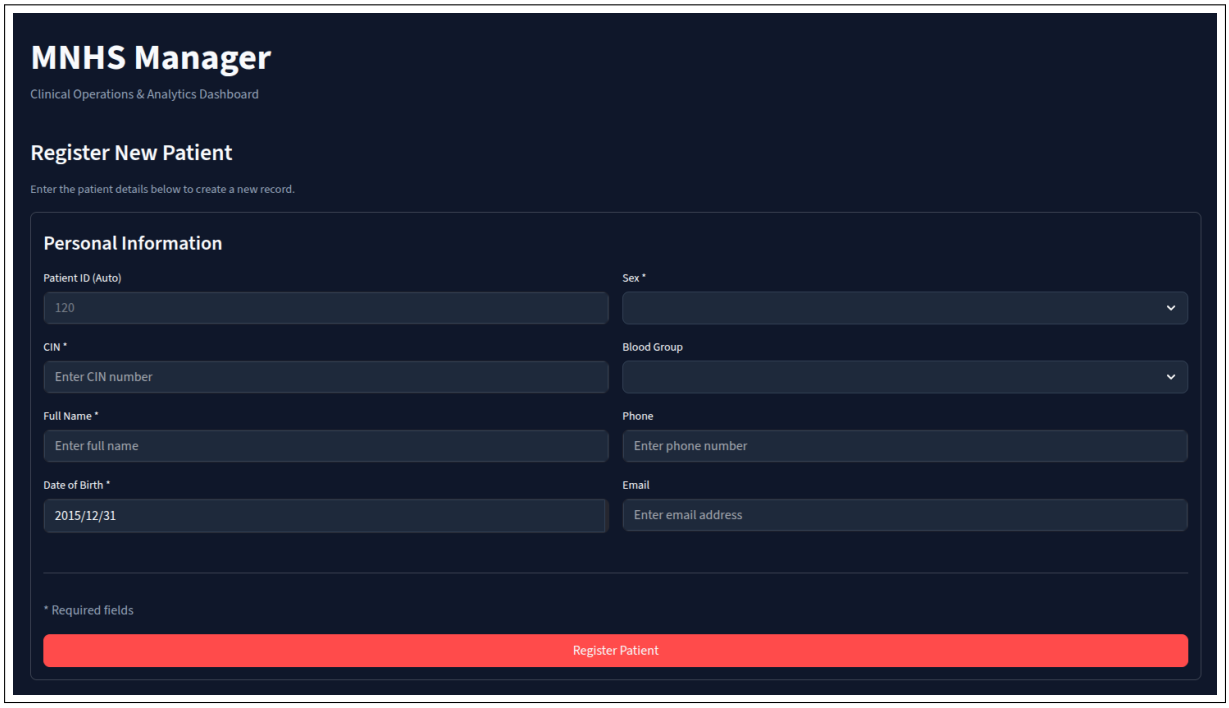


Figure 11: Add Patient Form

2.4 Adaptation Strategy: Handling TiDB Limitations

A core requirement of the lab specification was the implementation of four specific SQL Triggers to enforce business rules. However, the backend selected for this project, **TiDB**, does not currently support the `CREATE TRIGGER` statement found in standard MySQL 5.7.

To maintain functional parity with the requirements while leveraging the scalability of TiDB, the application implements a **Python Based Validation Architecture**. All constraints normally enforced by the database engine were migrated to the Python application layer.

The Requested Triggers were written as requested in 1.2 Triggers this choice was only made to allow deployement of the app while enforcing buisness rules.

The only trigger that was implemented is the double-booking prevention trigger as it is the only one needed in the tasks that were specified in the Lab.

2.4.1 The "No-Trigger" Architecture

In a traditional architecture, the database acts as the final gatekeeper of data integrity using procedural SQL. In this adapted architecture, the Python plays this role.

2.4.2 Double-Booking Prevention

Requirement: The system must reject an appointment request if the staff member is already scheduled for the exact same Date and Time.

1. **Verification Query:** Before any write operation, the application executes a `SELECT` query on the `ClinicalActivity` table, filtering by the requested `STAFF_ID`, `Date`, and `Time`.

2. **Conflict Detection:** The results are analyzed using `cursor.fetchone()`. If a record is returned, the time slot is identified as occupied.

3. **Transaction Abort:** Instead of letting the database throw a constraint error, the Python application explicitly raises a `ValueError`. This halts the execution flow immediately, preventing the `INSERT` statements from running and triggering a `ROLLBACK` of the transaction.

```
# 1. Validation SQL: Check if staff is already booked
check_sql = """
    SELECT CAID FROM ClinicalActivity
    WHERE STAFF_ID = %s AND Date = %s AND Time = %s LIMIT 1
"""

# ... Inside the transaction ...
cur.execute(check_sql, (staff_id, date_str, time_str))
conflict = cur.fetchone()

if conflict:
    # STOP! Raise an error to prevent the insert
    raise ValueError(f"Double Booking Error: Staff {staff_id} is
       already busy.")
```

```
14
15 # If no conflict, proceed with the transaction
16 cur.execute(ins_ca, ...)
17 cur.execute(ins_appt, ...)
```

Listing 35: Double Booking Check Implementation

The full Python function can be found in 2.3.2 Module 2 : Intelligent Scheduling System

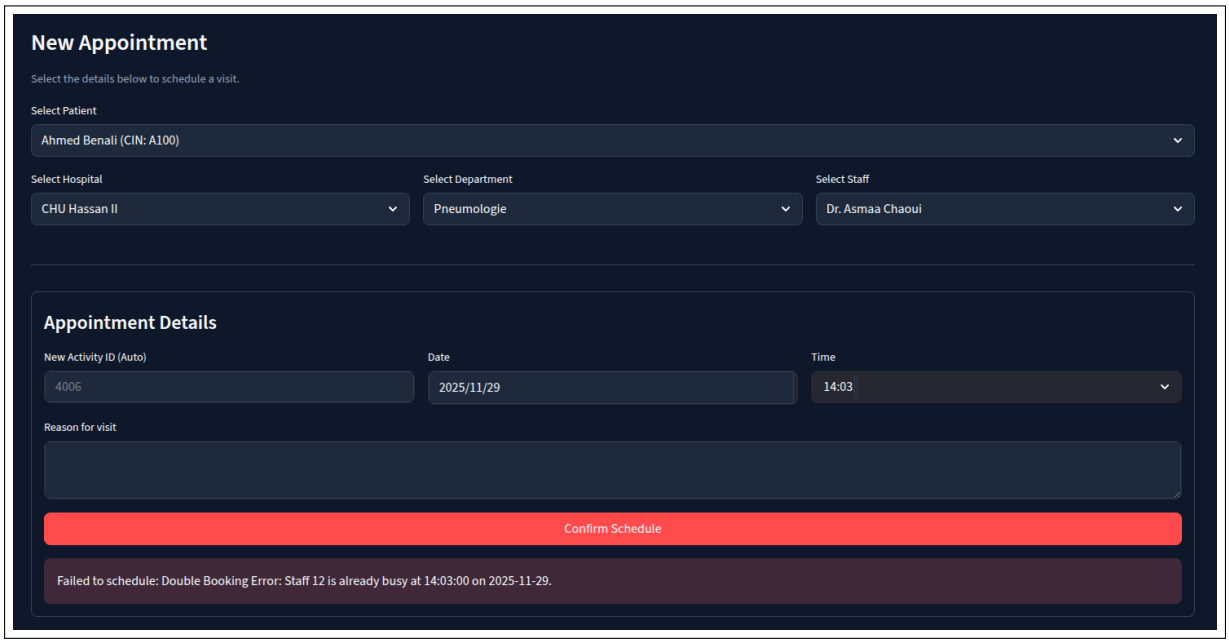


Figure 12: Double Booking Error Message

2.5 Conclusion

2.5.1 Summary of Achievements

This application layer successfully delivered a robust, full-stack "Application Layer" for the Moroccan National Health Services (MNHS) database. By integrating a Python-based Streamlit frontend with a distributed TiDB backend, the solution effectively bridges the gap between complex relational data and end-user accessibility.

Key technical achivements include:

- **Transactional Integrity:** The scheduling module ensures that the database maintains consistent states, even during complex multi-table write operations.
- **Architectural Adaptability:** The successful migration of business logic (constraints and validations) from the database layer to the application layer demonstrated the flexibility required when working with modern distributed SQL engines like TiDB, which may lack legacy features like Triggers.

2.5.2 Performance and Scalability

The chosen technology stack offers significant advantages for future growth. The use of **TiDB** ensures that the backend can scale horizontally to handle millions of patient records without complexity, while maintaining MySQL protocol compatibility. Furthermore, the **Streamlit** framework showed that complex, interactive dashboards can be deployed rapidly with a minimal code, making the system highly maintainable and easy to extend with new modules in the future.

2.6 Disclosure of AI Utilization

To maximize development efficiency and ensure a modern user interface, the frontend component of this application was developed with the assistance of Generative AI tools.

While the core database logic and SQL architecture were designed based on the lab specifications, We selected the **Streamlit** framework for the frontend interface. As we had no prior experience with this specific library, AI assistance was utilized to generate the initial code for the UI components (e.g., sidebars, forms, and layout containers).

It is important to note that we made a concerted effort to analyze, debug, and fully understand the generated code. The in-depth technical explanations provided in 2.3 Implementation and Code Logic, along with the specific code snippets details, serve as evidence of our understanding of the codebase.

2.7 Appendices

Project Repository and Source Code
To maintain the readability of this report, the full source code for the application is hosted in a public GitHub repository. This repository serves as the definitive source for the project's codebase, version history, and configuration files.

Repository Link:
`https://github.com/I-l-y-a-Z-z/DBMSApplicationLayerDeliverable5`

Local Deployment and Database Replication
The repository includes all necessary files to replicate the project environment locally:

- **Comprehensive Documentation (`README.md`):** A detailed guide providing step-by-step instructions for setting up the Python virtual environment, installing dependencies via `pip`, and launching the Streamlit server.
- **Database Generation Script (`query.sql`):** A monolithic SQL script is provided to fully reconstruct the MNHS database schema and populate it with the hyper-realistic dataset described in this report. This allows the application to be tested in a local MySQL or TiDB environment without requiring access to the production cluster.

Live Demonstration
For immediate testing and evaluation purposes, the application has been deployed to the Streamlit Cloud platform. This live instance connects directly to the production TiDB cluster, allowing users to interact with the full system functionality without the need for local installation or configuration.

Live Application URL:
`https://mnhslab6.streamlit.app`