Infectious Virus Management System

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Abstract

The Infectious Virus Management System is a comprehensive database designed to manage and analyze data related to infectious viruses. This database captures various aspects of virus management, including information on viruses, countries, cases, deaths, vaccines, research, testing labs, and quarantine facilities. By leveraging the data stored in this system, valuable insights can be gained regarding the spread of viruses, mortality rates, effectiveness of vaccines, and the preparedness of different countries in managing virus outbreaks. The Infectious Virus Management System showcases the significance of data-driven decision-making and effective database management in combating infectious diseases, protecting public health, and informing public health strategies and interventions.

Introduction

The Infectious Virus Management System project is a comprehensive database designed to effectively manage and analyze data related to infectious viruses. This project aims to provide a reliable and efficient system for tracking, analyzing, and responding to viral outbreaks. By centralizing essential virus-related information, the system offers valuable insights to researchers, healthcare professionals, policymakers, and other stakeholders involved in virus management.

The motivation behind this project stems from the ongoing threat of infectious diseases and the need for proactive measures to combat them. Recent global pandemics have highlighted the critical importance of having robust systems in place to track, analyze, and respond to viral outbreaks effectively. The Infectious Virus Management System addresses this need and contributes to the advancement of public health initiatives.

The primary goal of the Infectious Virus Management System is to design and implement a comprehensive database that centralizes essential virus-related data, enabling users to perform various analyses and gain valuable insights. The system encompasses several key features and use cases, including:

1. **Mortality Analysis:** Analyzing the mortality rates of different viruses by considering the total number of deaths in relation to the total number of cases. This analysis helps identify the deadliest viruses and prioritize resources for mitigation efforts.

2. **Preparedness Assessment:** Assessing the preparedness of countries for viral outbreaks by evaluating the ratio of total quarantine facility capacity to population. This assessment helps identify countries that are well-equipped to handle potential outbreaks and those that require additional resources.

3. **Transmission Mode Analysis:** Investigating viruses with specific transmission modes,

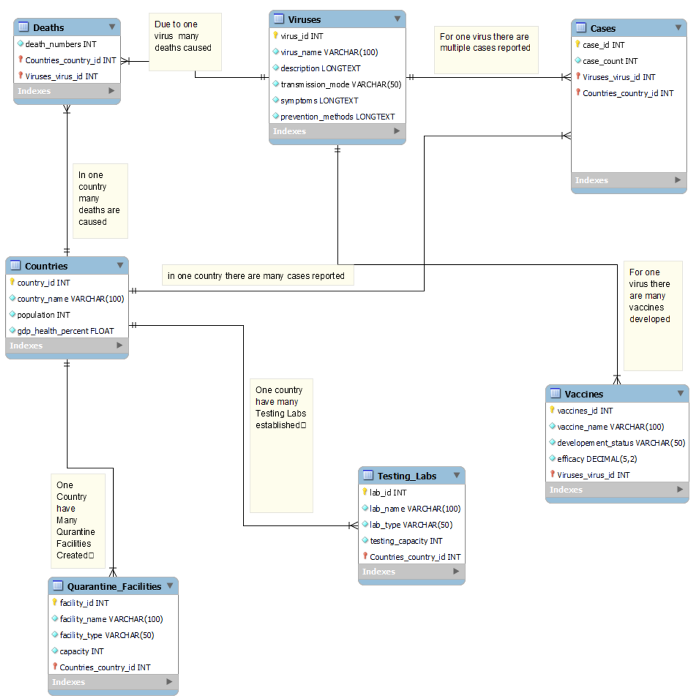
such as "Mosquito Bites." This analysis provides insights into the prevalence of viruses transmitted through specific mechanisms and helps guide preventive measures.

4. **Vaccine Efficacy Evaluation:** Evaluating vaccines by identifying the vaccine with the highest efficacy and the one with the lowest efficacy for each virus. This analysis aids in determining the most effective vaccines for different viral strains.

By incorporating these features and use cases, the Infectious Virus Management System empowers users with valuable insights, enhances decision-making processes, and contributes to improved virus management strategies.

In the following sections, we will delve into the database design, query examples, and discuss the implications of our findings. Let's explore the exciting world of infectious virus management and harness the power of data-driven approaches to combat infectious diseases effectively.

Database Design



The database is designed to efficiently store and manage data related to viruses, countries, cases, vaccines, testing labs, quarantine facilities, and deaths. The database schema consists of several interconnected tables, each representing a key entity and its attributes. Let's explore the key entities and their relationships:

1. **Viruses Table:** This table stores information about different viruses. It includes attributes such as virus_id (primary key), virus_name, description, transmission_mode, symptoms, and prevention_methods. The virus_id is referenced as a foreign key in other tables to establish relationships.

2. **Countries Table:** The Countries table contains data related to different countries. It includes attributes such as country_id (primary key), country_name, population, and gdp_health_percent. This table provides essential information about countries involved in virus management.

3. **Cases Table:** The Cases table tracks the reported cases of viruses in different countries. It includes attributes such as case_id (primary key), virus_id (foreign key referencing Viruses table), country_id (foreign key referencing Countries table), and case_count. This table establishes the relationship between viruses, countries, and the number of reported cases.

4. **Vaccines Table:** The Vaccines table stores information about vaccines developed for specific viruses. It includes attributes such as vaccine_id (primary key), virus_id (foreign key referencing Viruses table), vaccine_name, development_status, and efficacy. This table helps track the effectiveness and status of different vaccines.

5. **Testing_Labs Table:** The Testing_Labs table contains data about testing laboratories in various countries. It includes attributes such as lab_id (primary key), lab_name, country_id (foreign key referencing Countries table), lab_type, and testing_capacity. This table helps manage and monitor testing capabilities in different regions.

6. **Quarantine_Facilities Table:** The Quarantine_Facilities table stores information about quarantine facilities available in different countries. It includes attributes such as facility_id (primary key), facility_name, country_id (foreign key referencing Countries table), facility_type, and capacity. This table tracks the capacity and types of quarantine facilities for effective outbreak management.

7. **Deaths Table:** The deaths table records the number of deaths associated with specific viruses in different countries. It includes attributes such as virus_id (foreign key referencing Viruses table), country_id (foreign key referencing Countries table), and death_numbers. This table helps analyze mortality rates and establishes the relationship between viruses, countries, and deaths.

The database design ensures the proper organization and management of essential data related to viruses, countries, cases, vaccines, testing labs, quarantine facilities, and deaths. The relationships between these entities enable efficient data retrieval and analysis, supporting various use cases such as mortality analysis, preparedness assessment, transmission mode analysis, and vaccine efficacy evaluation.

Data Sources and Methods

Acquiring and preparing the data for the Infectious Virus Management System project involved several steps and sources. Here is a step-by-step explanation of the data acquisition process:

1. **Data Generation**: To create a comprehensive dataset, we used Python code to generate random numbers for most of the data fields. This approach allowed us to simulate diverse scenarios and ensure a wide range of values for analysis.

2. **Research for Viruses Table**: The data for the viruses table was not generated randomly. Instead, we conducted extensive research on the internet to gather accurate information about various viruses. This involved collecting data such as virus names, descriptions, transmission modes, symptoms, and prevention methods. The sources used for this research are cited in the references.

3. **Data from World Bank's World Development Indicators**: For the countries table, we sourced the data from the World Bank's World Development Indicators [1]. This

reputable resource provides us with reliable information about countries, including their names, populations, and GDP health percentages.

4. **Data Cleaning and Modification**: Prior to loading the data into the database, we performed necessary data cleaning and modifications. This included ensuring data integrity, validating data types, and handling any inconsistencies or outliers. The generated data was carefully reviewed and cleaned to eliminate any unrealistic values.

After acquiring and preparing the data, we organized it into CSV (Comma-Separated Values) files to facilitate easy importation into the MySQL Workbench. Each table's data was stored in a separate CSV file, maintaining the same structure as the corresponding database table.

The CSV files were then imported into the MySQL Workbench using the appropriate import functionality. This process involved mapping the columns in the CSV files to the corresponding table columns in the database. By utilizing this approach, we ensured a seamless transfer of data from the CSV files into the database tables.

References: [1] World Bank. World Development Indicators. Available at: https://databank.worldbank.org/source/world-development-indicators#

By following this methodology, we maintained a structured and organized approach to data management, allowing for efficient storage and retrieval of information within the database.

Data Analysis

The following questions were framed, and each question was answered using a SQL query which aimed to provide an accurate result. The queries have been included and described below:

1. Retrieve the top 5 countries with the highest number of cases for a specific virus:

The question aims at retrieving the list of the top five countries with the highest number of cases for that virus. This will help us understand which countries have been affected the most by that virus and take the appropriate preventive measures to stop the spread of the disease.

```sql
SELECT c.country_name, SUM(ca.case_count) AS total_cases
FROM Countries c
JOIN Cases ca ON c.country_id = ca.country_id
JOIN Viruses v ON v.virus_id = ca.virus_id
WHERE v.virus_name = 'HIV'
GROUP BY c.country_name
ORDER BY total_cases DESC
LIMIT 5;
```

This query retrieves the top 5 countries with the highest number of cases for a specific virus, such as HIV. It joins the **Countries**, **Cases**, and **Viruses** tables based on their respective IDs and filters the results based on the virus name. The query then groups the data by country name and calculates the total cases for each country. Finally, it sorts the results in descending order and limits the output to the top 5 countries. This query provides insights into the countries that are most affected by a specific virus, helping in the development of targeted healthcare systems and interventions. For example, we entered the virus "HIV" for this query and obtained the following result.

	country_name	total_cases
▶	Seychelles	993157
	Netherlands	993117
	Greece	993022
	Croatia	992996
	Congo, Dem. Rep.	992988

From the output, we can clearly understand that the most affected country is Seychelles with total number of cases for HIV is 993157 followed by a case count of 993117 in the country of Netherlands. This helps us understand that the problem of HIV is mostly in these two countries.

2. For each virus, retrieve the virus name, the vaccine with the highest efficacy, along with its development status and efficacy value, as well as the vaccine with the lowest efficacy, along with its development status and efficacy value:

The question aims at understanding the most and least effective vaccine available for each vaccine in the current market along with its development status.

```sql
SELECT v.virus_name,
       vc_max.vaccine_name AS highest_efficacy_vaccine,
       vc_max.development_status AS highest_efficacy_status,
       vc_max.efficacy,
       vc_min.vaccine_name AS lowest_efficacy_vaccine,
       vc_min.development_status AS lowest_efficacy_status,
       vc_min.efficacy
FROM Viruses v
JOIN (
    SELECT virus_id,
           MAX(efficacy) AS max_efficacy,
           MIN(efficacy) AS min_efficacy
    FROM Vaccines
    GROUP BY virus_id
) sub ON v.virus_id = sub.virus_id
JOIN Vaccines vc_max ON vc_max.virus_id = sub.virus_id AND vc_max.efficacy = sub.max_efficacy
JOIN Vaccines vc_min ON vc_min.virus_id = sub.virus_id AND vc_min.efficacy = sub.min_efficacy;
```

This query retrieves information for each virus, including the virus name, the vaccine with the highest efficacy, its development status, and efficacy value. It also identifies the vaccine with the lowest efficacy, its development status, and efficacy value. The subquery calculates the maximum and minimum efficacy values for each virus, and the main query joins the **Viruses** table with the subquery results to retrieve the corresponding vaccine details.

The output gives us the vaccines with the highest and lowest efficacy for each virus. For example, in the output below

virus_name	highest_efficacy_vaccine	highest_efficacy_status	efficacy	lowest_efficacy_vaccine	lowest_efficacy_status	efficacy
COVID-19	COVID-19 Vaccine B	Approved	0.96	COVID-19 Vaccine D	Approved	0.93
Influenza	Influenza Vaccine A	Approved	0.85	Influenza Vaccine H	Development	0.67
Ebola	Ebola Vaccine E	Approved	0.93	Ebola Vaccine C	Development	0.68
Zika	Zika Vaccine B	Approved	0.88	Zika Vaccine A	Development	0.68
SARS-CoV	SARS-CoV Vaccine B	Experimental	0.83	SARS-CoV Vaccine D	Development	0.65
HIV	HIV Vaccine F	Experimental	0.72	HIV Vaccine A	Development	0.45
Measles	Measles Vaccine B	Approved	0.98	Measles Vaccine F	Approved	0.95
Measles	Measles Vaccine G	Approved	0.98	Measles Vaccine F	Approved	0.95
Malaria	Malaria Vaccine F	Experimental	0.81	Malaria Vaccine A	Experimental	0.62
Dengue	Dengue Vaccine D	Approved	0.92	Dengue Vaccine A	Development	0.55
Chikungunya	Chikungunya Vaccine C	Development	0.74	Chikungunya Vaccine A	Experimental	0.72
Chikungunya	Chikungunya Vaccine D	Development	0.74	Chikungunya Vaccine A	Experimental	0.72
Hepatitis B	Hepatitis B Vaccine B	Approved	0.92	Hepatitis B Vaccine C	Experimental	0.66
Tuberculosis	Tuberculosis Vaccine C	Approved	0.93	Tuberculosis Vaccine A	Development	0.58
Norovirus	Norovirus Vaccine C	Development	0.78	Norovirus Vaccine A	Experimental	0.75
West Nile virus	West Nile Vaccine B	Approved	0.89	West Nile Virus Vaccine C	Experimental	0.81
Yellow fever	Yellow Fever Vaccine C	Approved	0.96	Yellow Fever Vaccine A	Experimental	0.67
Hantavirus	Hantavirus Vaccine D	Development	0.68	Hantavirus Vaccine A	Development	0.53
Lyme disease	Lyme Disease Vaccine A	Experimental	0.79	Lyme Disease Vaccine A	Development	0.65
Avian influenza	Avian Influenza Vaccine A	Approved	0.93	Avian Influenza Vaccine A	Development	0.61
MERS-CoV	MERS-CoV Vaccine A	Approved	0.93	MERS-CoV Vaccine B	Development	0.75
Rabies	Rabies Vaccine A	Experimental	0.78	Rabies Vaccine D	Experimental	0.57
Cholera	Cholera Vaccine A	Approved	0.95	Cholera Vaccine B	Experimental	0.72
Hepatitis C	Hepatitis C Vaccine B	Approved	0.88	Hepatitis C Vaccine D	Development	0.47

For the virus Influenza the vaccine A has the highest efficacy of 85% and is approved for usage while the vaccine H has the least efficacy of 67% and is still in the development stage. This query allows for the determination of the most and least effective vaccines available for each virus, aiding in the evaluation and comparison of vaccine effectiveness.

3. Determine which countries are prepared for an outbreak. (i.e., which countries have a ratio of total quarantine facility capacity to population less than 1:100)

It is crucial to understand which countries are prepared for an outbreak (be it any infectious disease). This can help understand which countries to target to develop the existing quarantine facilities and be prepared in case an outbreak happens.

```
SELECT c.country_name,
       SUM(qf.capacity) AS total_capacity,
       c.population,
       CASE WHEN SUM(qf.capacity) / c.population >= 0.01 THEN 'PREPARED'
            ELSE 'NOT PREPARED'
       END AS prepared_status
FROM Countries c
LEFT JOIN Quarantine_Facilities qf ON qf.country_id = c.country_id
GROUP BY c.country_id, c.country_name, c.population;
```

This query determines which countries are prepared for an outbreak by calculating the ratio of total quarantine facility capacity to population. It joins the **Countries** and **Quarantine_Facilities** tables based on country IDs and sums the quarantine facility capacities for each country. The query then compares the ratio of capacity to population and assigns a "PREPARED" or "NOT PREPARED" status based on whether the ratio is less than 1:100.

	country_name	total_capacity	population	prepared_status
▶	Afghanistan	368592	38972230	NOT PREPARED
	Algeria	264153	43451666	NOT PREPARED
	Andorra	219112	77700	PREPARED
	Angola	255986	33428486	NOT PREPARED
	Antigua and Barbuda	376832	92664	PREPARED
	Argentina	235532	45376763	NOT PREPARED
	Armenia	172058	2805608	PREPARED
	Australia	278559	25655289	PREPARED
	Austria	262183	8916864	PREPARED
	Azerbaijan	239667	10093121	PREPARED
	Bahamas, The	321589	406471	PREPARED
	Bahrain	139329	1477469	PREPARED
	Bangladesh	245831	167420951	NOT PREPARED
	Barbados	239694	280693	PREPARED
	Belarus	297051	9379952	PREPARED
	Belgium	325734	11538604	PREPARED
	Belize	327792	394921	PREPARED
	Benin	227446	12643123	PREPARED
	Bhutan	233603	772506	PREPARED
	Bolivia	258187	11936162	PREPARED
	Bosnia and Herzego...	182421	3318407	PREPARED
	Botswana	252070	2546402	PREPARED
	Brazil	127153	213196304	NOT PREPARED
	Brunei Darussalam	243894	441725	PREPARED

The output clearly categorizes the countries that are prepared and those that are not prepared for an outbreak. For example, Afghanistan is not prepared because of the ratio of total_capcity to the population of the country dropping below 0.01. Whereas countries like Armenia and Azerbaijan are well prepared because of the ratio being more than 0.01. This query helps assess a country's preparedness for an outbreak by examining its quarantine facility capacity relative to population size.

4. Which viruses have the transmission mode 'Mosquito Bites', and what is the total number of cases for each virus? Additionally, for each virus, which country has the highest number of cases? What prevention methods must be implemented by the citizens of that country?

The question aims to analyze the transmission of viruses through “mosquito bites” by identifying the specific viruses involved and determining the total number of cases for each virus. Additionally, it seeks to identify the country with the highest number of cases for each virus and highlight the prevention methods that should be implemented by the citizens of those countries. By addressing these aspects, the question aims to gain insights into the prevalence and spread of mosquito-borne viruses, identify high-risk areas, and propose targeted prevention strategies to mitigate their impact on public health.

```sql
SELECT v.virus_name, SUM(c.case_count) AS total_cases, ch.country_name AS country_with_highest_cases, v.prevention_methods
FROM Viruses v
JOIN Cases c ON v.virus_id = c.virus_id
JOIN (
    SELECT virus_id, country_name
    FROM Cases c
    JOIN Countries co ON c.country_id = co.country_id
    WHERE c.case_count = (
        SELECT MAX(case_count)
        FROM Cases
        WHERE virus_id = c.virus_id
    )
) ch ON v.virus_id = ch.virus_id
WHERE v.transmission_mode = 'Mosquito Bites'
GROUP BY v.virus_id, v.virus_name, ch.country_name, v.prevention_methods
ORDER BY total_cases DESC;
```

This query focuses on viruses with the transmission mode of 'Mosquito Bites'. It retrieves the total number of cases for each virus and identifies the country with the highest number of cases for each virus. It also provides information on the prevention methods that should be implemented by the citizens of that country. The query joins the **Viruses**, **Cases**, and **Countries** tables to retrieve the necessary data and uses subqueries to identify the country with the highest number of cases for each virus. We yield the following output for this query:

virus_name	total_cases	country_with_highest_cases	prevention_methods
Zika	97450740	United Arab Emirates	Mosquito control, safe sex practices
Yellow fever	94031537	Thailand	Vaccination, mosquito control
West Nile virus	93438068	Thailand	Mosquito control, wearing protective clothing
Malaria	92520103	Slovenia	Insecticide-treated bed nets, anti-malarial medication
Dengue	89793511	Poland	Mosquito control, avoiding mosquito bites
Chikungunya	87589826	Italy	Mosquito control, pain management

From the output it is very clear that UAE is most effected by the Zika virus while a country like Thailand is affected the most by the yellow fever and West Nile Virus. This helps us understand where the prevention methods for the virus must be invoked with immediate effect to encounter the spread of the disease.

5. What are the viruses with the highest mortality rates, considering the total number of deaths in relation to the total number of cases?

This question aims to identify the viruses with the highest mortality rates by considering the ratio of total deaths to the total number of cases. By analyzing the data, the goal is to determine which viruses pose a greater risk to human life and have a higher fatality rate. This information is crucial for understanding the severity and impact of different viruses, enabling healthcare professionals and policymakers to prioritize resources, develop effective prevention strategies, and allocate appropriate medical interventions to combat the most dangerous viruses.

```sql
SELECT v.virus_name,
       SUM(d.death_numbers) AS total_deaths,
       SUM(c.case_count) AS total_cases,
       (SUM(d.death_numbers) / SUM(c.case_count)) * 100 AS mortality_rate
FROM deaths d
JOIN Viruses v ON d.virus_id = v.virus_id
JOIN Cases c ON d.virus_id = c.virus_id
GROUP BY v.virus_id, v.virus_name
ORDER BY mortality_rate DESC;
```

This query calculates the mortality rate for each virus by considering the total number of deaths in relation to the total number of cases. It joins the Viruses, Deaths, and Cases tables based on virus IDs and calculates the mortality rate by dividing the total deaths by the total cases. The results are sorted in descending order based on the mortality rate. We get the following output for this query:

virus_name	total_deaths	total_cases	mortality_rate
COVID-19	1920119474	15188156438	12.6422
Influenza	1903518526	15408878576	12.3534
Hepatitis C	1951088412	15861280162	12.3010
Zoonotic influenza	1926544802	15799452032	12.1937
SARS-CoV	1914528616	16028987884	11.9442
Ebola	1955164848	17160904124	11.3931
Zika	1986504156	17736034680	11.2004
Avian influenza	1770352038	15878093686	11.1497
Chikungunya	1759999696	15941348332	11.0405
Hantavirus	1839462352	16881762898	10.8962
West Nile virus	1849212456	17005728376	10.8741
Yellow fever	1852096064	17113739734	10.8223
Dengue	1761943456	16342419002	10.7814
Influenza	1868686820	17480474466	10.6901
MERS-CoV	1757627144	16458163722	10.6794
Lyme disease	1797564860	16873289706	10.6533
HIV	1862191058	17615542672	10.5713
Malaria	1762126184	16838658746	10.4648
Cholera	1778894572	17513729506	10.1571
Rabies	1788161830	17799013778	10.0464
Norovirus	1728766858	17312479184	9.9857
Measles	1748739538	17552798354	9.9627
Hepatitis B	1653811068	16717793456	9.8925
Tuberculosis	1692579434	17423440580	9.7144

Thus, we understand that diseases like COVID-19 and Influenza are the deadliest viruses having mortality rates of 12.64% and 12.35%. While diseases like TB and Hepatitis B are the least deadly viruses with a mortality rate of 9.71% and 9.89%.

Conclusions

The project successfully designed and implemented a database system to manage and analyze information related to viruses, countries, cases, vaccines, testing labs, quarantine facilities, and deaths. The database provided valuable insights into various aspects of viral diseases and public health preparedness. Through the queries executed on the database, several key findings were obtained.

Firstly, the top 5 countries with the highest number of cases for a specific virus were identified, allowing for targeted healthcare interventions. Secondly, the most and least effective vaccines for each virus were determined, aiding in vaccine development and administration decisions. Additionally, the preparedness of countries for outbreaks was assessed based on their quarantine facility capacity in relation to population size. Furthermore, the database enabled the identification of viruses transmitted through mosquito bites, along with the total number of cases and the country with the highest case count for each virus. Lastly, the database facilitated the identification of viruses with the highest mortality rates by considering the ratio of deaths to total cases.

While the project achieved its goals, it is important to acknowledge its limitations. Firstly, the data used, except for viruses and countries, was synthesized using Python code, which may not fully represent real-world scenarios. Additionally, the database design and queries were based on assumptions and requirements specific to this project and may not encompass all possible use cases. Furthermore, the accuracy and completeness of the data depend on the sources from which it was obtained. It is crucial to continuously update and validate the database with reliable and up-to-date information to maintain its relevance and usefulness.

In summary, this project's database system provided valuable insights into viral diseases, vaccine efficacy, public health preparedness, and mortality rates. It serves as a foundation for further analysis and research in the field of infectious diseases and healthcare planning. However, future work should focus on incorporating more comprehensive and accurate data, expanding the database's functionalities, and collaborating with domain experts to enhance its applicability in real-world scenarios.

Author Contributions

The author’s contributions for this project were as follows: Deepro Bose and Gopi Krishna Oggu jointly conceived the idea for the project and shared the responsibility for its execution. Gopi primarily focused on the database design, ensuring the proper structure and relationships among the tables. He worked diligently to create an efficient and effective database schema. On the other hand, Deepro focused on formulating and implementing the queries to extract meaningful insights from the database. Deepro devoted his efforts to crafting queries that addressed specific questions and provided valuable information. Both authors collaborated closely throughout the project, exchanging ideas, discussing strategies, and reviewing each other's work to ensure the project's success.

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