Exploring the Insights of COVID-19 Vaccination using Visual Analytics Approach

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Abstract - *Vaccination has been introduced and is being administered for the deadly disease of the year 2019 known as the novel coronavirus disease, COVID-19; but still the virus continues to spread in such a rapid phase across the world that there is a needto study it thoroughly. We have aimed to analyze and visualize the current standpoint of the fight against this epidemiological outbreak. In this work, we have used visual analytics to analyze, for providing a clear picture of the current situation in terms of its daily vaccinations, total vaccinations administered in eachcountry, the number of fully vaccinated people, and thereby provide means for tracking the COVID-19 vaccination progress globally. Also, we have developed a dashboard successfully for serving this purpose which answers specific questions such as which are the vaccines used in each country, which country ranks first in terms of vaccination administered, what is the current status of vaccination in each country, how many vaccines are available in the world, and which is the most popular vaccine being used. We are committed to our society in increasing the public awareness of this infectious disease by analyzing and visualizing the detailed information of the vaccination which are not answered by the existing dashboards which is the major meritof this work.*

Key Words: **COVID-19, Pandemic, Vaccination, Visual Analytics, Exploratory Data Analysis, Visual Exploratory Data Analysis.**

1.INTRODUCTION

The novel coronavirus disease, nCoV-2019, later renamed as COVID-19 by World Health Organization (WHO) was first reported in Wuhan, a city in Hubei province in China. It has then managed to spread across 192 countries. COVID-19 outbreak was growing at such a rapid phase that the WHO declared it as the sixth Public Health Emergency of International Concern (PHEIC) on 30th January 2020 [1]. H1N1 in 2009, Ebola virus in West Africa in 2014, Polio in 2014, Zika virus in 2016, and Ebola virus in the Democratic Republic of Congo in 2019 were the preceding five PHEIC. Dr.Tedros Adhanom Ghebreyesus, the director-general of WHO later renamed it COVID-19 on 11th February 2020. Due tothe rapid outspread of COVID-19, later WHO declared it as Pandemic on 11th March 2020.

Most of the infected patients show mild symptoms like fever, headache, shortness of breath, diarrhea, etc. to severe symptoms and even may lead to death. There are also certain cases where the infected patients are asymptomatic in nature, i.e., they do not show any signs or symptoms. Dueto the significance of this global health issue, COVID-19 has attained great attention from public health researchers globally. Scientists from across the world are working as quickly as possible in cooperating and developing various tests, effective treatments, and safe vaccines that may accordingly rescue livesand put an end to this pandemic. Vaccines can save countless lives annually. Each vaccine works by training and preparing our immune system to identify and fight against the viruses and other disease-causing germs that they aim at. Once vaccinated,if the body gets exposed to any of such disease-causing germs,the body is instantly able to destroy them, preventing them from being affected by the illness.

As of February 18, 2021, a minimum of 7 varieties of vaccines across 3 platforms has been administered in countries.Vaccines are said to be a crucial tool in the battle againstthe contagious disease, COVID-19 and it is great immense to ascertain such a big amount of vaccines proving successful and stepping into further development. We know that safeand effective vaccines will surely prove to be a gamechanger; but for the foreseeing future, we must continue wearing masks, maintain social distancing, and avoid the crowd. Being immunized doesn't mean that we have got the permission to throw away caution to the wind and place our lives and the lives of others in danger as it is still not clear to what extend the vaccines will shield us not only against this deadly diseasebut also against its spread and transmission.

In our study, we are analyzing and visualizing the available COVID-19 vaccination dataset to track the vaccination progress in each country using a dashboard. We are trying to find answers to certain questions like:

- What is the current status of vaccination in each country?
- Which country ranks first in terms of vaccinations administered?

- How many varieties of vaccines are available globally?
- Which is the most popular vaccine being used?
- Which are the vaccines used in each country?

2. RELATED WORKS

Through an exploratory study within the scope of innovation management, a method aims to identify and explore factors that are promoting the accelerated development scenario of COVID-19 vaccination and this method consists of the monitoring of the strategies adopted by the developers and other stakeholders for its development [2]. A summarized report on cell receptor interactions and that on prospects of new vaccinestargeting the deoxyribonucleic acid (DNA), messenger ribonucleic acid (mRNA), and viral minigenes was produced on June 27, 2020, and they have also tabulated the available data on various clinical trials testing various aspects of COVID-19 vaccines [3]. Dr. Nicole Lurie explains in detail the rapid COVID-19 vaccine development and also explains new tools to facilitate vaccine testing and manufacturing and persistent challenges [4]. Simran Preet Kaur and Vandana Gupta in their review, have mentioned the platforms for COVID-19 vaccine development, clinical trials, use of preformed antibodies, and vaccine development and their limitations [5]. An exploratory data analysis approach was proposed to collect and analyzethe COVID-19 dataset to study its epidemiological outbreak [1, 6, 7]. Data analytics was applied on the various available COVID-19 datasets to clearly understand the outbreak cases and to get a clear picture of the situation which helps in taking necessary precautionary measures [8, 9]. Visualization techniques along with data analytics were also used for analyzing and visualizing the epidemiological outbreak of COVID-19 [10 – 15]. Kamel Boulos and Geraghty in their review paper mentioned a range of practical online/mobile GIS and mapping dashboards and applications for tracking the 2019/2020 coronavirus epidemic and various associated events around the world [16]. In our search for related works, we came across certain review papers on various online/mobile applications for tracking the novel coronavirus disease [17,18, 19]. Painter, Elizabeth M et al. analyzed one month ofdata available for obtaining the demographic characteristicsof persons vaccinated during the first month of the COVID-19 vaccination program in the United States from December 14th, 2020, to January 14th, 2021 [20].

3. COVID-19 VACCINES

COVID-19 vaccines are those vaccines that help us fight against this deadly disease by boosting our immune system effectively. These are built up of smaller quantities of germs that are weak or dead. By vaccinating a person, we are introducingthese weak or dead germs into their body which accelerates their immune system by developing antibodies against these germs and fight against them if any germs attack them. As germs or viruses can quickly spread through a community and affect a larger population, vaccination not only protects you but also protects those who are surrounding you. COVID-19 vaccines that are currently available are based on 4 different approaches.

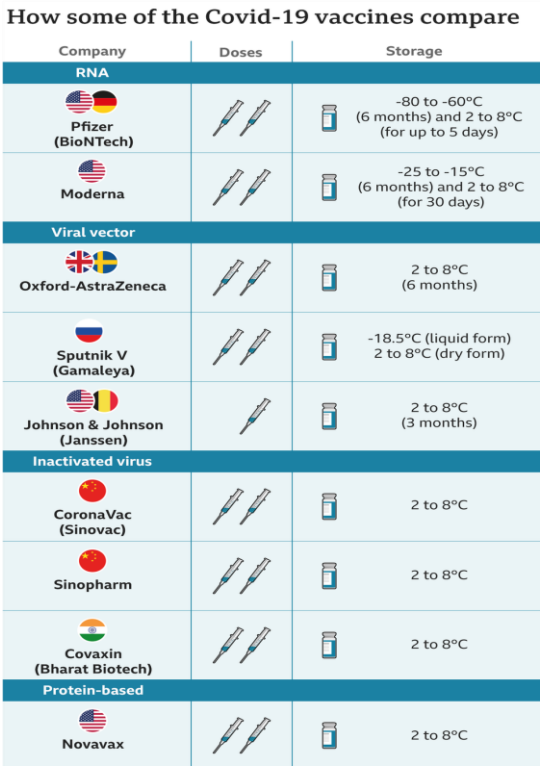

Fig -1: Comparison of various COVID-19 vaccines

They are whole virus, protein subunit, viral vector,and nucleic acid. Whole virus vaccines consist of two main approaches – a weakened or inactivated version of the COVID-19 virus. Protein subunit vaccines utilize fragments of theCOVID-19 virus or pieces of protein to accelerate an immune response. Nucleic acid vaccines make use of the genetic substance to give instructions to the cells to accelerate our immune response. The genetic substance can be either RNAor DNA. In this case, the given instruction is to produce the COVID-19 'spike' protein which boosts immune response. Viral vector vaccines also work by giving instructions to the cells to produce antigens against the COVID-19 virus. It usesa harmless virus that is modified to contain part of the genetic material of COVID-19. Fig. 1 illustrates the vaccines that wereinitially available as per BBC reports. Besides the vaccines shown in the figure, several other vaccine candidates are at their various stages of trials. Some of them are ZyCov-Di, HGCO19, etc.

4. VISUAL ANALYTICS

We, humans, are visual learners, i.e., we understand visuals better than any other written form of data. Therefore, visualization of any form of data makes more sense for us. Hence, therearises the importance of the field of Visual Analytics which is acombination of Data Analytics and

Data Visualization. Visual Analytics can be thought of as a technique that consolidates visualization, various human elements, and data analysis. Several techniques are available for visualizing the data. Data analytics deals with the science of analyzing raw facts totransform them into more meaningful and useful information. Data visualization comprises the tools and techniques used forpresenting data as graphs or images which helps in identifying and understanding the concepts more clearly. In the context of data visualization, visual analytics can be related to the area of information visualization and computer graphics, whereas, in the context of data analysis, it can be related to information retrieval, data management, knowledge representation, and data mining [21]. Visual Analytics leads to a better exploration of data and data analysis with minimized overall cost. It also provides faster and improved data understanding for making decisions faster. We can also consume huge volumes of datain a short time leading to better operational efficiency. It also provides instant feedback and real-time updates keeping data up-to-date and accurate.

5. ANALYSIS OF COVID-19 VACCINATION

Our study aims to analyze and get into the deeper information of the available COVID-19 vaccination dataset. The analysis was performed using Python in Jupyter Notebook. Fig. 2 illustrates the steps involved in this analysis purpose.

5.1 Data Collection

Data collection is the predominant step in any data analytical process. It deals with the collection of the requisite quantity of data from numerous available data sources. The analysis was performed on the open dataset provided by Gabriel Preda in the Kaggle repository [22]. He also provides an opportunityfor the researchers and data analysts to analyze his dataset by updating it frequently. He is taking the dataset provided by another website named "Our World in Data" which updates the data in their GitHub repository for COVID-19 [23]. Itis then merged with details like the name of the vaccinesadministered, their source name, etc., and finally uploaded in the Kaggle repository. Another dataset based on the number of vaccinations per country split by manufacturer is also providedby him. The reason why we are not using the live dataset from"Our World in Data" is that it doesn't contain any data related to the names of the vaccines and their source name. Here,we have downloaded the dataset that was latest updated byhim on July 7, 2021, in the Kaggle repository. Then, we have uploaded this dataset to our GitHub repository from where we are retrieving the dataset in real-time in this step of data collection.

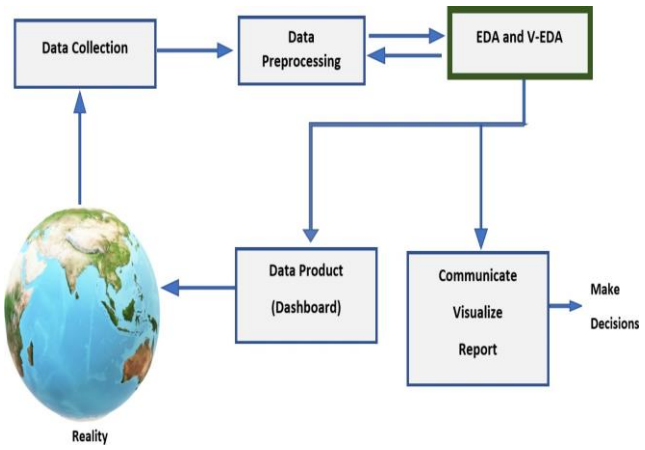

Fig -2: Overview of analysis

5.2 Data Preprocessing

The next major step after the foremost step, data collection is the data preprocessing step. This step is essential as it is necessary to realize the data that we have collected in our previous step and do some preprocessing as the collected data may contain unnecessary data. The process of converting data into various forms that are appropriate for carrying out further exploration and analysis purposes is known as Data transformation. Data cleaning, data normalization, etc. are some of the other tasks that are involved in the preprocessing step [24]. The data available consists of various formats of noise and there may also be problems related to their quality too, urging for the preprocessing step. In such situations, data cleaning plays a significant role since it converts raw data intosome other useful forms. Certain techniques like replacement of missing or null values, removal of additional spaces, and conversion of textual data into some other useful formats are used for eliminating the outliers and noises that are present in the dataset. This conversion of data from one format to another useful format is known as data conversion. After successfully collecting, cleaning, and converting data into some useful formats, extraction of the necessary features for our analysis purpose is done. This process is known as feature extraction. In our study, the number of COVID-19 vaccination progressin terms of the number of daily vaccinations, the total number of vaccinations, total vaccinations per 100 people, number of fully vaccinated people, etc. are the most important features that are extracted.

5.3 Visual Exploratory Data Analysis (V-EDA)

The approach that we use for the purpose of analysis and visualization of the variety of datasets that are available online to get deeper insights from them is known as Exploratory Data Analysis (EDA). It is the main approach that is used by scientists to familiarize themselves with data. EDA methods are mainly classified into 4 categories, namely, univariate non- graphical methods, multivariate non-graphical methods, univariate graphical methods, and multivariate graphical methods.In our case study, we are

analyzing the dataset so that we can obtain a better understanding of the current progress in COVID-19 vaccination in each country. Various methods can

5.4 Development and Deployment of Online Dashboard

The work that we have implemented in Jupyter Notebook using Python is then converted into an interactive dashboard with the help of the Voila framework. Finally, our interactive dashboard was successfully deployed using Heroku. Thereby, providing an opportunity for the users to run our dashboard onany system or mobile without the need for installing Pythonor Jupyter Notebook to analyze and visualize the information regarding COVID-19 vaccination details.

6. ANALYSIS RESULTS

Here, in our study, we are analyzing the number of COVID- 19 vaccinations administered in each country including daily vaccinations, the total number of vaccinations, etc. and also the vaccines administered in each country, the most popular vaccine all over the world for the time being from 12th December 2020 to 22nd June 2021. Hence, a comparative analysis of all the details related to COVID1-9 vaccination is provided through this study. There was a total of 179425040042 vaccinations administered till 6th July 2021 and the total numberof people that got fully vaccinated till the same as per reports is 39026601444.

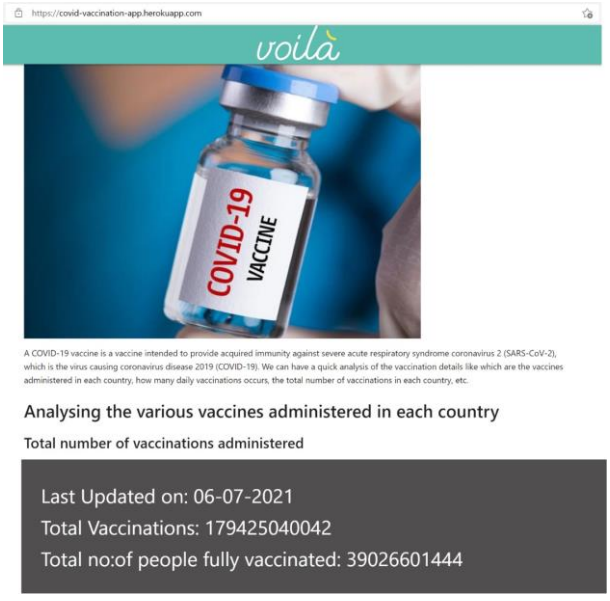

Fig -3: A screenshot of the COVID-19 vaccination visualization dashboard.

We have analyzed the dataset that was downloaded from theKaggle repository as a part of our study using various EDA methods and we were able to uncover many details that lie hidden within it. Fig. 3 shows a screenshot of the dashboard that was created for visualizing the COVID-19 vaccination asa part of our analysis. The link to the above dashboard is https://covid-vaccination-app.herokuapp.com/. Fig. 4 shows a table displaying the top countries in descending order based on their total number of vaccinations administered in each country. There is also an option for choosing the details of up to 30 countries. Here, we have only displayed the top 10 countries along with daily vaccinations administered, number of fully vaccinated people in each country based on the descending order of their total number of vaccinations. Fig. 5 represents a table displaying the top vaccines that are being administered across the world along with the number of countries where they are given.

To clearly understand the details of the COVID-19 vaccination, we have plotted bar charts, pie charts, choropleth maps, treemaps, and heatmaps to analyze and visualize the data related to COVID-19 vaccinations across the world in each country. By plotting bar charts, we are plotting categoricaldata related to COVID-19 vaccinations. Figures Fig. 6, 7, and 8 shows bar charts related to vaccination details. Fig. 6 illustratesthe vaccinations that are most widely used on July 6th, 2021. Fig. 7 depicts the top countries with total vaccinations per100 people, and Fig. 8 shows the top countries with fully vaccinated people. Figures, Fig. 7 and 8 also have an optionto choose details of up to 30 countries. Then we have plotteda pie chart to show the visual representation of the COVID- 19 vaccinations data in terms of the vaccines used in each country. Here, in our case, the number of slices is equal to the number of vaccines that are being administered in each country across the world. Fig. 9 illustrates the pie chart of the vaccines used against the fight of COVID-19. The chart will also display the total number of countries where each vaccine is being administered.

n 10

	country	vaccines	daily_vaccinations	total_vaccinations	people_fully_vaccinated
0	China	CanSino, Sinopharm/Beijing, Sinopharm/Wuhan, Sinovac	22424286.000000	1331669000.000000	223299000.000000
1	India	Covaxin, Oxford/AstraZeneca, Sputnik V	6276153.000000	354307646.000000	65525089.000000
2	United States	Johnson&Johnson, Moderna, Pfizer/BioNTech	3384387.000000	331214347.000000	157636088.000000
3	Brazil	Oxford/AstraZeneca, Pfizer/BioNTech, Sinovac	1436195.000000	107628177.000000	28160641.000000
4	United Kingdom	Moderna, Oxford/AstraZeneca, Pfizer/BioNTech	602266.000000	79302857.000000	33874176.000000
5	Germany	Johnson&Johnson, Moderna, Oxford/AstraZeneca, Pfizer/BioNTech	861028.000000	77892414.000000	32696003.000000
6	England	Moderna, Oxford/AstraZeneca, Pfizer/BioNTech	515433.000000	66540378.000000	28432362.000000
7	France	Johnson&Johnson, Moderna, Oxford/AstraZeneca, Pfizer/BioNTech	584754.000000	57152332.000000	23027275.000000
8	Turkey	Pfizer/BioNTech, Sinovac	1264431.000000	55004225.000000	16140197.000000
9	Italy	Johnson&Johnson, Moderna, Oxford/AstraZeneca, Pfizer/BioNTech	582574.000000	54193516.000000	20858991.000000

Fig -4: Table displaying top countries in the descending order based on their total no:of vaccinations administered.

As per choropleth maps, we are illustrating a thematic map representation of the world with areas shaded based on each COVID-19 vaccine used. Figure Fig. 10 shows the choropleth maps based on the combination of vaccines used in each country across the world. Treemaps are then plotted illustrating the number of COVID-19 vaccinations. Figures Fig. 11, 12, and 13 depict the resulting treemap based on the number of people vaccinated grouped by COVID-19 vaccines used in each country. We could easily recognize the top countries based on the number of vaccinations administered from these treemaps. Fig. 11, and 12 show the treemap of the top countries with daily vaccinations per country and total vaccinations per country respectively grouped by vaccines administered in each country. Fig. 13 shows the treemap of top countries with the number of fully vaccinated people grouped by vaccines administered in each country.

Finally, heatmaps were plotted to show the relationship between the COVID-19 vaccination details. Heatmaps are mainly used to find the multicollinearity of the data and it also helps in determining which are the

	vaccines	country
0	Oxford/AstraZeneca	125
1	Moderna	30
2	Johnson&Johnson	27
3	Pfizer/BioNTech	12
4	Sinopharm/Beijing	8
5	Covaxin	6
6	CanSino	4
7	EpiVacCorona	2
8	Abdala	1
9	QazVac	1
10	Sputnik V	1

Fig -5: Table displaying the top vaccines along with the number of countries where they are administered on 22-06-2021.

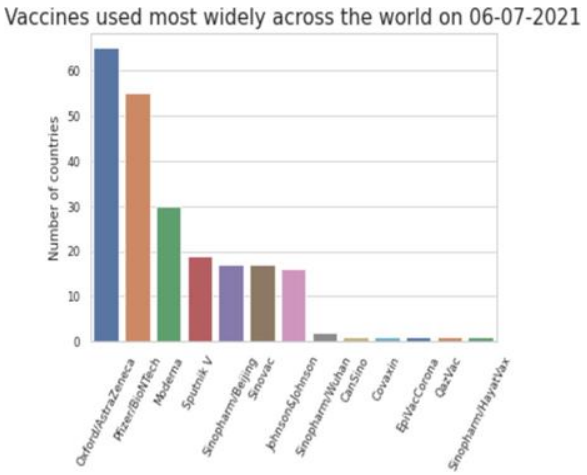

Fig -6: Bar plot showing the vaccines most widely used across the world as reported on 06-07-2021.

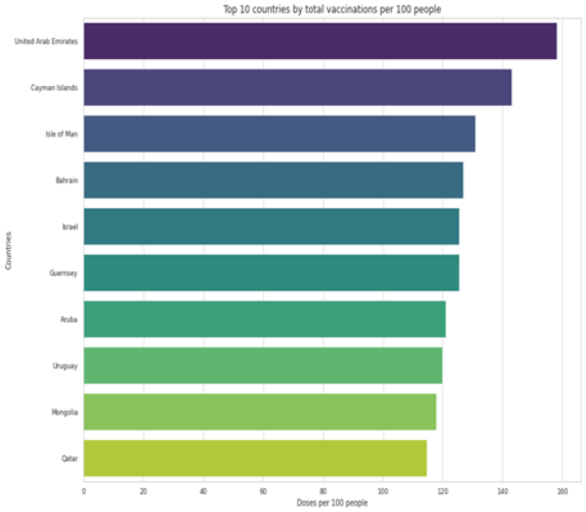

Fig -7: Bar plot showing top countries with total vaccinations per 100 people.

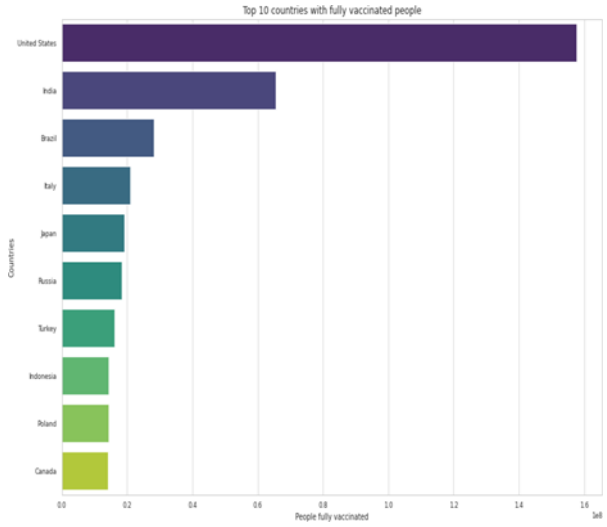

Fig -8: Bar plot showing top countries with fully vaccinated people.

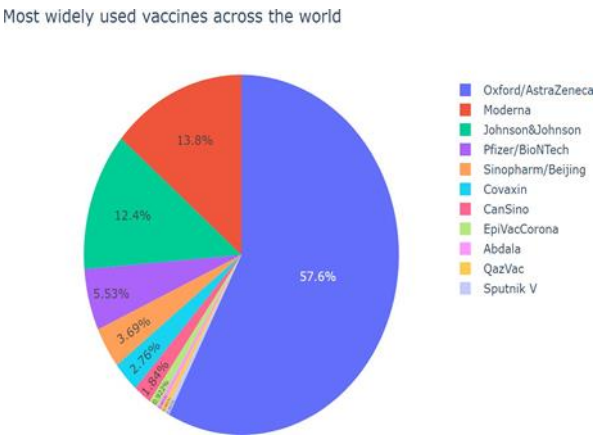

Fig -9: Pie chart displaying the top vaccines along with the number of countries where they are administered.

values that should be kept or to be discarded as a part of our analysis and visualization results. Multicollinearity refers to the state where an independent variable within it can be highly correlated to more than one variable. Usually, the x-axis values are considered, and if the value lies close enough to zero, then it represents a weak relationship, and these values will be discarded. If the values lie close to 0.85, then it shows a high correlation between the data values, known as multicollinearity. Multicollinearity tendsto reduce the interpretation quality of the independent variables within a dataset. Hence, multicollinearity should be eliminated to do a proper interpretation of the vaccination dataset. Fig. 14represents the heatmap of the vaccination data showing their correlation.

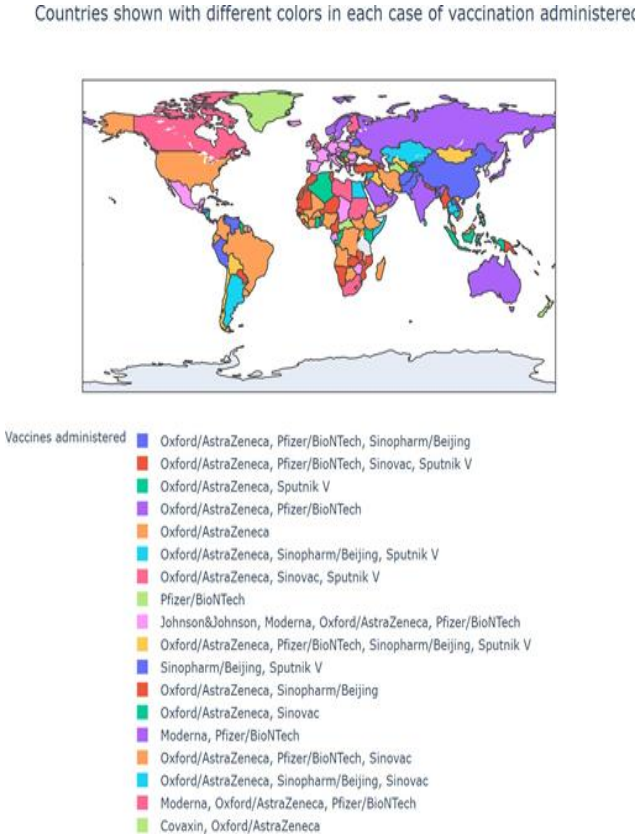

Fig -10: Choropleth map showing the countries along with vaccines administered in it.

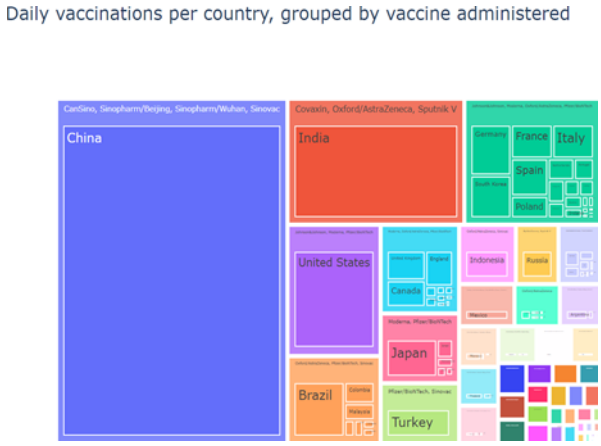

Fig -11: Tree map showing daily vaccinations per country, grouped by vaccineadministered.

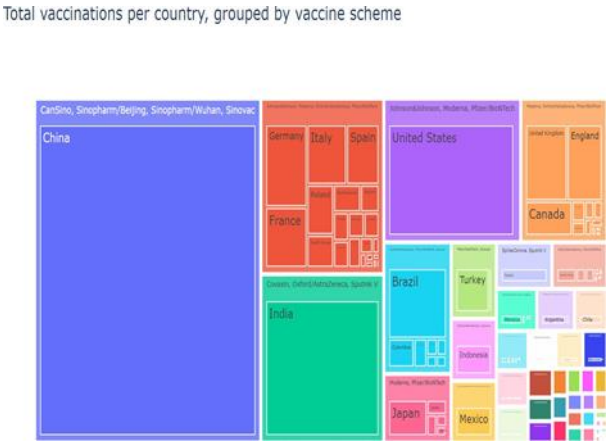

Fig -12: Tree map showing total vaccinations per country, grouped by vaccineadministered.

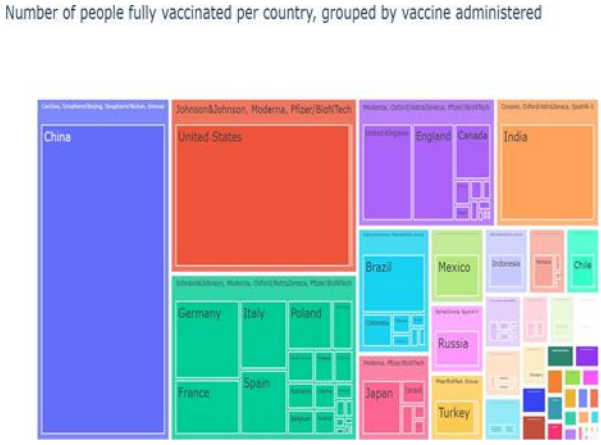

Fig -13: Tree map showing fully vaccinated people per country, grouped byvaccine administered.

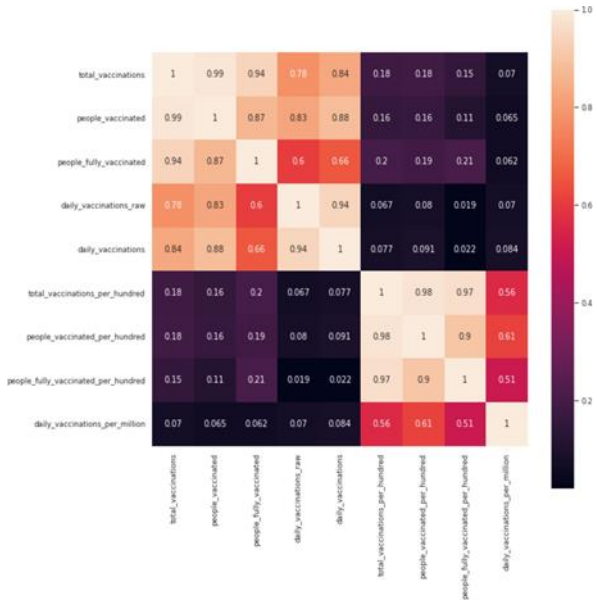

Fig -14: Heatmap displaying the relationship between various statistical variables.

7. DISCUSSION

We have analyzed and visualized all the details related to the COVID-19 vaccination that were available in the dataset provided by Gabriel Preda in his Kaggle repository. The dataset that we have considered contained data from December 12th, 2020 to July 6th, 2021. An increase in the number of vaccinations was found during the analysis and visualization of the COVID-19 vaccination dataset that was available on Kaggle which is updated by the owner frequently. In our study, all the data analytical process was done using Python on Jupyter Notebook and several python-based libraries were used for this purpose, and the dashboard was created using Voila. Some of the libraries that were utilized for this are NumPy, Pandas, Matplotlib, Plotly, and Seaborn. As a part of our analysis, we were able to develop and deploy a dashboard (https://covid-vaccination-app.herokuapp.com/) and also plot bar charts, pie charts, choropleth maps, treemaps, and heat maps with the help of these python-based libraries to obtain a clear picture of the progress in COVID-19 vaccination understandably and interactively. From our analysis, we have found that 14 types of vaccines are currently being administered across the world and these are shown through the use of various visual methods. It was also found that countries could use several vaccines for fighting against the COVID- 19 disease. These findings are not obtained from any other available dashboards which only focus on the COVID-19 cases and not on the vaccination details. We can rarely find the details of vaccination from the dashboard and that too is related to the details such as the number of people getting vaccinated in each country, and not many details of the vaccines administered globally. For comparison, we can consider the dashboard provided by Johns Hopkins University dashboard given in the link https://coronavirus.jhu.edu/map.html provides you the details of the vaccine doses administered globally and not providing any details of the vaccines administered in each country, which is the key point of our dashboard.

8. CONCLUSIONS

The entire world is disquiet by the novel pandemic COVID-19 that is caused by the third type of virus from the Coronaviridae family, due to the increase in its fatality rate. In the beginning, the pandemic was not under control as it lacked lots of information. Later, we could keep the virus under control until the second wave of the deadly disease, COVID- 19 outbreak was found in the United Kingdom. As a result of many sleepless nights of health researchers from across the world, they have somehow managed to come up with few vaccines against this severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2). Even though vaccines are being administered across the world, we all are under the fear of getting affected by this pandemic anytime, anywhere, and anyhow; no matter to which age group we belong to. All are being equally affected by COVID-19 until we remain locked under the safe doors of our home.

In this analysis, we are trying to analyze and visualize the data related to the COVID-19 vaccination that is available in the Kaggle repository using a dashboard built and deployed for this purpose. Since we cannot simply hinge upon the available statistical numbers alone, a thorough and continuous analysis of the data is required. Also, human brains understand visuals better than any other form of written data. Hence, we are utilizing the magical power of interactive visualization to get a clear picture of the current progress of the COVID-19 vaccination. As far as we know, this study is the first attempt focusing on analysis and visualization performed on the COVID-19 vaccination dataset over this time period. From our analysis, we have found that 14 types of vaccines are currently being administered across the world and these are shown through the use of various visual methods. It was also found that countries could use several vaccines for fighting against the COVID-19 disease. Proper analysis and visualization of this vaccination surely help in generating and disseminating thorough knowledge of COVID-19 vaccination to the community.

REFERENCES

[1] Samrat K. Dey, Md. Mahbubur Rahman, Umme R. Siddiqi and Arpita Howlader, “Analyzing the epidemiological outbreak of COVID-19: A visual exploratory data analysis approach,” Journal of Medical Virology, vol. 92, no. 6, pp. 632-638, 2020.

[2] Defendi, H.G.T., da Silva Madeira, L. and Borschiver, S, “Analysis of the COVID-19 Vaccine Development Process: an Exploratory Study of Accel-erating Factors and Innovative Environments,” Journal of Pharmaceutical Innovation, 2021.

[3] Khan I, Ahmed Z, Sarwar A, Jamil A, and Anwer F, "The potential vaccine component for COVID-19: a comprehensive review of global vaccine development efforts," Cureus, vol. 12, no. 6, 2020.

[4] Lurie N, Saville M, Hatchett R, and Halton J, "Developing Covid-19 vaccines at pandemic speed," Virus Research, vol. 288, 2020.

[5] Simran Preet Kaur, and Vandana Gupta, "COVID-19 Vaccine: A comprehensive status report," N Engl J Med., vol. 382, no. 21, pp. 1969–73, 2020.

[6] Dey, S.K., Rahman, M., Siddiqi, U.R. et al., "Exploring Epidemiological Behavior of Novel Coronavirus (COVID-19) Outbreak in Bangladesh," SN Compr. Clin. Med., vol. 2, pp. 1724–1732, 2020.

[7] Dey SK, Rahman MM, Siddiqi UR, and Howlader A, "Early Outbreak Analysis of COVID-19 Epidemic: China and Global Health Perspectives,"Research Square, 2020.

[8] M. Rubaiyat Hossain Mondal, Subrato Bharati, Prajoy Podder, Priya Podder,"Data analytics for novel coronavirus disease," Informatics in Medicine Unlocked, 2020.

[9] Noopur Khare, Meenakshi Jha, Runjhun Mathur, and Abhimanyu Kumar,"Data Analysis for COVID-19," The International journal of analytical and experimental modal analysis,vol. 12, no. 5, 2020.

[10] Nikhat Akhtar, Nazia Tabassum, Asif Perwej, and Yusuf Perwej, "Data analytics and visualization using Tableau utilitarian for COVID-19 (Coro-navirus) ," Global Journal of Engineering and Technology Advances, vol. 3, no. 3, pp. 028–050, 2020.

[11] Abhishek Parikh, Sandeep Shah, and Vishvam Bhatt, "Data Analytics and Visualization Techniques of Corona Impact," International Journal ofComputer Science and Network, vol. 9, no. 4, 2020.

[12] Ritik Dixit, Rishika Kushwah, and Samay Pashine, "Analysis of COVID-19 Impact using Data Visualization," International Journal for Research in Applied Science Engineering Technology, vol. 8, no. 5, 2020.

[13] S. K. Saini, V. Dhull, S. Singh and A. Sharma, "Visual Exploratory Data Analysis of COVID-19 Pandemic," 2020 5th IEEE International Conference on Recent Advances and Innovations in Engineering (ICRAIE), pp. 1-6, 2020.

[14] J. Alsakran and L. Alnemer, "Visual Analysis of COVID-19 Trends," 2020 Seventh International Conference on Information Technology Trends (ITT), pp. 196-201, 2020.

[15] H. Raj and R. K. Mishra, "Data Analysis of Novel Coronavirus Based onMultiple Factors," 2020 Seventh International Conference on Information Technology Trends (ITT), pp. 135-139, 2020.

[16] Maged N. Kamel Boulos and Estella M. Geraghty, "Geographical tracking and mapping of coronavirus disease COVID-19/severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) epidemic and associated events around the world: how 21st century GIS technologies are sup- porting the global fight against outbreaks and epidemics," International Journal of Health Geographics, 2020.

[17] M. N. Islam, I. Islam, K. M. Munim and A. K. M. N. Islam, "A Review on the Mobile Applications Developed for COVID-19: An Exploratory Analysis," IEEE Access, vol. 8, pp. 145601-145610, 2020.

[18] H. Ren, J. Shen, X. Tang and T. Feng,"5G Healthcare Applications In COVID-19 Prevention And Control," 2020 ITU Kaleidoscope: Industry- Driven Digital Transformation (ITU K), pp. 1-4, 2020.

[19] V. Sree D. and M. T. Paul V.,"A study on COVID-19 app's satisfaction user attitude in digital combat of coronavirus pandemic," 2020 4th International Conference on Electronics, Communication and Aerospace Technology (ICECA), pp. 1207-1212, 2020.

[20] Painter, E. M., Ussery, E. N., Patel, A., Hughes, M. M., Zell, E. R., Mou-lia, D. L., Scharf, L. G., Lynch, M., Ritchey, M. D., Toblin, R. L., Murthy,

B. P., Harris, L. Q., Wasley, A., Rose, D. A., Cohn, A., and Messonnier, N. E, "Demographic Characteristics of Persons Vaccinated During the First Month of the COVID-19 Vaccination Program - United States, December 14, 2020-January 14, 2021," Morbidity and mortality weekly report, vol. 70, no. 5, pp. 174–177, 2021. https://doi.org/10.15585/mmwr.mm7005e1

[21] Bernhard Preim, and Kai Lawonn, "A Survey of Visual Analytics for Public Health," Journal of Computer Graphics Forum, vol. 39, no. 1, pp. 543-580, 2020.

[22] Gabriel Preda, "COVID-19 World Vaccination Progress," Kaggle, 2021. Available: https://www.kaggle.com/gpreda/covid-world-vaccination-progress. [Accessed: 07-07-2021].

[23] Our World in Data, "covid-19-data, " GitHub, 2021. Available: https://github.com/owid/covid-19-data

[24] Lakshmi. M. B, Dr. M. Rajeswari, Rehna Baby Jospeh, Emily Joy,Aleena Varghese, Anju P, and Ashly Roy, "Understanding the epidemiological outbreak of COVID-19: Visual Exploratory Data Analysis," in Emerging Technologies in Engineering Research, Dr.G.Ramprabu, Technical Research Publications, ch. 14, pp. 167-181, 2020.

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