Visualizing Pandemics with Calendar Heatmaps : A Case Study of Covid-19 in Malaysia

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Abstract

The COVID-19 pandemic has had a significant impact on Malaysia, with over 4 million cases and 30,000 deaths reported as of January 2023. This has led to a need for new approaches to visualize and analyze COVID-19 data in order to support decision-making and public health interventions. The chapter proposes a calendar heatmap visualization approach for COVID-19 data in Malaysia where it allows users to easily compare different metrics, such as daily cases and deaths across different time periods. This can be helpful for identifying trends and patterns in the spread of the virus, as well as for understanding the impact of different interventions. The proposed approach is implemented as a web-based system using the D3.js algorithm. The results showed that the calendar heatmap visualization approach was effective in helping users to understand COVID-19 trends and patterns. It could be used to support a variety of decision-making processes, such as planning vaccination campaigns, allocating resources, and implementing public health interventions. The approach could be extended to include additional metrics, such as the number of tests and recoveries, to support predictive analytics using machine learning models. It is a promising new tool for analyzing pandemic data as it is effective in identifying trends and patterns, and has the potential to be expanded to support a variety of decision-making processes in other types of pandemics such as HIV-Aids and influenza. It can be accessed by a wide range of stakeholders, including government officials, healthcare workers, and the general public.

Keywords: calendar heatmap; Covid-19; descriptive analytics; pandemics

INTRODUCTION

In recent times, many countries in the world witnessed the beginning of the end of the Covid-19 pandemic. However, as time progressed, a relatively stable situation unfolded. The emerging variants of the coronavirus observed thus far have shown a close resemblance to Omicron, with no significant alterations in its overall impact (Rana *et al.* 2022) and Covid-19 remains a global health threat and experts continue to monitor its spread closely (Cascella *et al.* 2022).

In Malaysia, the Ministry of Health is maintaining its implementation of Covid-19 control and prevention measures according to established protocols (CodeBlue 2023) as Covid-19 cases continue to emerge and it is posing a significant risk of death, especially for elderly individuals with underlying health conditions. Therefore, it is crucial to conduct an in-depth analysis of the factors contributing to the country's struggles with controlling the spread of the virus (Shah *et al.* 2020). Prolonged periods of lockdown and social distancing measures have also had severe

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economic and social consequences, making it imperative to find effective solutions to combat the pandemic.

Data analytics plays a crucial role in understanding and addressing the complexities of the Covid-19 pandemic (Sheng *et al.* 2020). In the battle against the Covid-19 pandemic, data analytics emerges as a powerful tool, providing valuable insights and aiding decision-making processes. At the outset of the pandemic, users were compelled to manually search for Covid-19 cases, which was akin to searching for a document manually (Roser and Hannah 2020). The process required visualizing data by examining individual data points one-by-one, which can have detrimental effects on the brain and eyes due to prolonged screen exposure. Furthermore, the manual search and visualization process is time-consuming and dependent on individual imagination, resulting in a less efficient use of resources.

In this research, a Covid-19 descriptive visualization approach through heatmap is proposed where it can provide users with an intuitive and comprehensive overview, facilitating easy analysis of the pandemic's impact (Fernandez *et al.* 2017). The insights acquired by the heatmap visualization are targeted to contribute to the on-going efforts to combat the pandemic and minimize its economic and social consequences. The visualization approach also enables users to discern patterns in the data visualization. The result will show the differences between the primary visualization methods used, which is the Calendar Heatmap, and other visualization techniques such as the Bar Chart and Line Chart.

There are a variety of Covid-19 visualization approachesintroduced by companies, universities, hospitals and researchers (Comba and Comba 2020; So *et al.* 2020; Khanam *et al.* 2020). Our World in Dataproduces data visualization process the world problem Issues (Lounis 2021). It makes the knowledge on big problems accessible and understandable. The data visualization can be changed based on what the users need to see either table, graph or heatmap. The visualization of Our World in Data is shown in Figure 1. Its Covid-19 data visualization and analysis include a range of metrics such as case counts, testing rates, mortality rates, and vaccination rates. The website allows users to explore the data through interactive visualizations, tables, graphs, and heatmaps. Our World in Data is well-regarded for its data quality, methodology, and transparency in sourcing and presenting data.

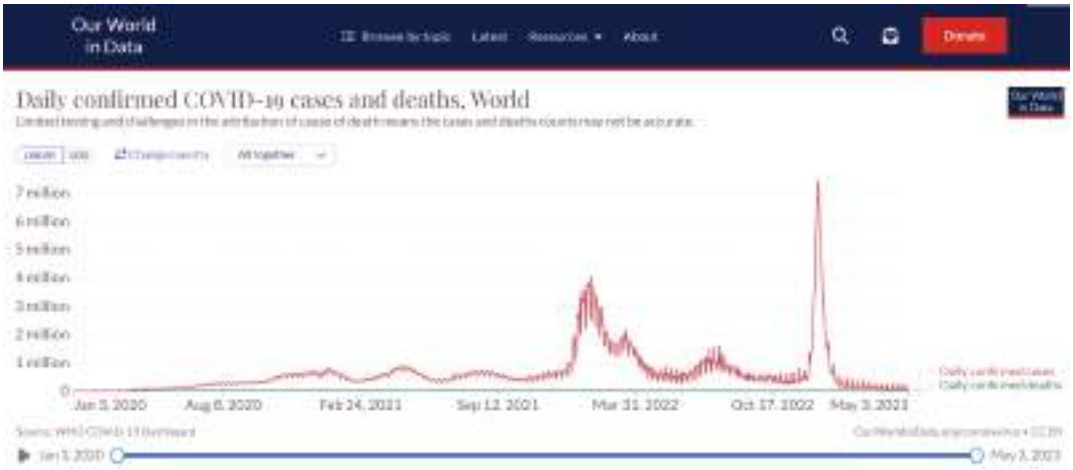

Figure 1 The main interface of Our World in Data website

Worldometer is a real-time statistics website that provides various information, including the Covid-19 pandemic (WorldOMeter 2023). It has been widely used by researchers and policymakers. The website updates Covid-19 data from multiple sources, including the World Health Organization (WHO) and national health agencies. Worldometer provides data on confirmed cases, deaths, and recoveries, as well as graphs and maps to visualize the data. The website also provides demographic breakdowns of the data, such as age, gender, and pre-existing conditions. Worldometer's Covid-19 data has been cited in various research studies and media reports. Worldometer visualization is shown in Figure 2.

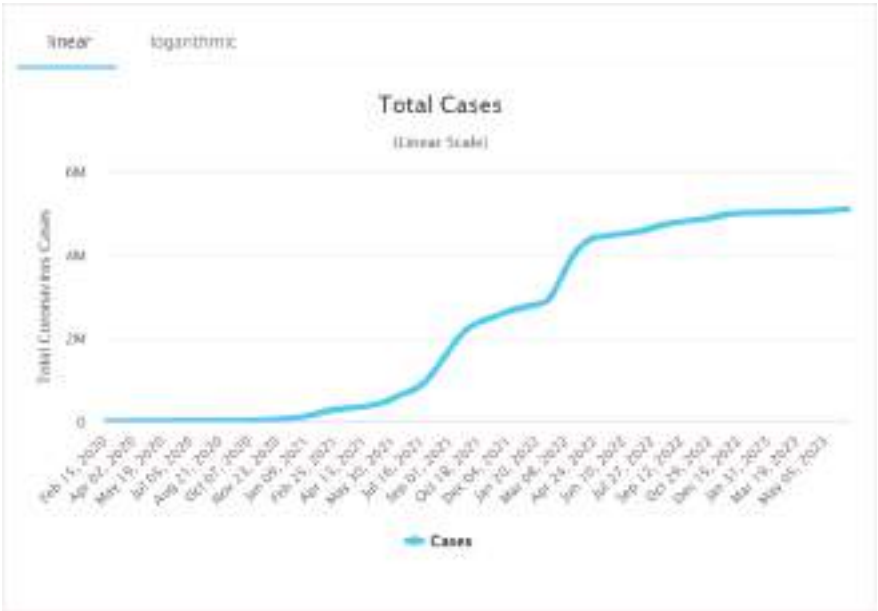

Figure 2 Worldometer Covid-19 cases visualization

The Covid-19 Tracker by the New York Times is a source for tracking the Covid-19 pandemic in the United States (the New York Times 2023). It provides up-to-date information on the number of cases, deaths, and hospitalizations in each state and county, as well as trends over time. It includes informative visualizations to help users better understand the spread of the virus. The New York Times uses data from various sources, including state and local health departments, to provide accurate and reliable information to its readers. Overall, the Covid-19 Tracker by the New York Times as shown in Figure 3 is targeted to individuals, healthcare professionals, and policymakers alike, in their efforts to combat the Covid-19 pandemic.

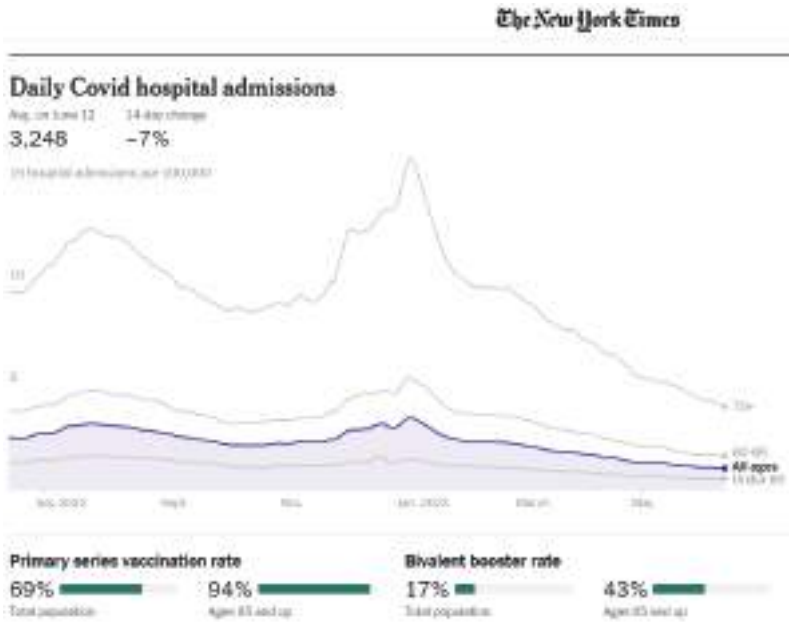

Figure 3 The Covid-19 Tracker by the New York Times

The Covid-19 Dashboard by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University is a tool for tracking the global spread of the Covid-19 pandemic (Dong *et al.* 2022). The dashboard shown in Figure 4 provides up-to-date information on confirmed cases, deaths, and recoveries, broken down by country, region, and state. The data is presented in a variety of visualizations, including maps, charts, and tables, allowing users to easily track trends and patterns in the spread of the virus. The dashboard has been used by public health officials and policymakers as a key source of information in their decision-making processes. It has also been used by the media to report on the latest developments in the pandemic.

Overall, the Covid-19 Dashboard by the CSSE at Johns Hopkins University has emerged as a valuable resource in the fight against the Covid-19 pandemic, providing critical information and insights to help policymakers, public health officials, and the public at large better understand and respond to the ongoing crisis.

Figure 4 Covid-19 Dashboard at Johns Hopkins University

The Ministry of Health Malaysia also offers visualization and analytics of Covid-19 trendsas shown in Figure 5 (Ismail *et al.* 2022; Hamzah *et al.* 2020). The website displayed many kinds of information about Malaysians trending health issues. The main page will display data visualization about trending disease. It also holds campaigns for Malaysian citizens to fight the trending disease.

Figure 5 The Ministry of Health Malaysia Website

The World Health Organization's Covid-19 visualization is a data-driven tool provided by the World Health Organization to effectively present and analyze Covid-19 related information (Tao *et al.* 2020; Wong 2023). This visualization platform offers interactive charts, maps, and graphs that allow users to explore and

understand various aspects of the pandemic. It provides visual representations of key data such as the number of confirmed cases, deaths, and recoveries globally and across different countries. The visualization tool also allows users to examine trends over time, compare data between regions, and assess the impact of interventions and measures implemented to control the spread of the virus. The World Health Organization's Covid-19 visualization is shown in Figure 6.

Figure 6 The World Health Organization Covid-19 Visualization

All of the above Covid-19 visualization approaches vary in their focus and offerings. Our World in Data and the New York Times Covid-19 Tracker emphasize data analysis and visualizations, Worldometer provides real-time statistics, the Johns Hopkins Covid-19 Dashboard is renowned for accuracy, Ministry of Health Malaysia website offer localized information, and the WHO Covid-19 Dashboard provides global data from a trusted source. Users can choose the approach that aligns with their specific needs, whether it's accessing global trends, tracking real-time updates, or finding localized information. The comparison of Covid-19 visualizations is shown in Table 1.

Table 1 Comparison of Covid-19 Visualization Websites

Covid-19 Visualization Websites	Target User	Type of Visualization
Our World in Data	General Public	Line Graph
Worldometer	General Public	Bar Graph, Line Graph
New York Times Covid-19 Tracker	General Public	Line Graph
Johns Hopkins Covid-19 Dashboard	General Public	Maps, Bar Graph
Ministry of Health Malaysia Website	Malaysian citizens	Text, Numbers
WHO Covid-19 Dashboard	General Public	Maps, Bar Graph

The remaining sections of this article are structured as follows. Section 2 presents the methodology implemented in this research. The implementation of the research is discussed in detail, particularly the methods used to perform specific tasks, along with screenshots of the process. Section 3 focuses on the results of the experiment and analysis. The aim of this stage is to obtain the outcomes of the development process, and any unexpected results that hindered the achievement of the research goal will be addressed in further cycles to rectify those issues. Finally, Section 4 provides a conclusion, summarizing the content derived from the research outcomes. Suggestions and future work to improve this research are also highlighted.

METHODS

Data Analytics Life Cycle for Covid-19 Descriptive Analytics Research

The Data Analytics Life Cycle for Covid-19 is a structured approach that encompasses various stages to extract meaningful insights from data related to the Covid-19 pandemic (Awotunde *et al.* 2021; Costa *et al.* 2021). It involves processes such as data collection, data cleaning and preprocessing, exploratory data analysis, and the application of statistical and visualization techniques to describe and summarize the Covid-19 data. By following this life cycle, researchers can uncover patterns, trends, and correlations in the data, leading to a comprehensive understanding of the descriptive aspects of the pandemic. The data analytics life cycle for Covid-19 is shown in Figure 7.

Figure 7 Data Analytics Life Cycle

1. Phase 1: Business Understanding and Requirement Gathering
   During this phase of the data analytics life cycle, the focus is on gaining a comprehensive understanding of the business context and requirements for Covid-19 descriptive analytics research. The objectives of the research are defined, and stakeholders' needs and expectations are identified. The functionality and scope of the data analytics, including data visualization of Covid-19 cases, are analyzed. The requirements for the research are collected and documented, considering available data sources and desired outcomes. This phase typically involves conducting research, interviews, and workshops to gather sufficient data and perform the necessary analysis.
2. Phase 2: Data Preparation and Exploration
   Based on the requirements defined in the previous phase, this phase focuses on preparing and exploring the data for analysis. Data from various sources, including Covid-19 datasets, are acquired and integrated. Data cleaning, transformation, and normalization techniques are applied to ensure data quality and consistency. Exploratory data analysis is performed to understand the characteristics and patterns in the Covid-19 data. Data visualization techniques may be used to gain insights and identify trends. The data is prepared and organized in a suitable format for analysis in the next phase.
3. Phase 3: Data Analysis and Modeling
   During this phase, the prepared data is analyzed and models are developed to extract insights and make predictions related to Covid-19 cases. Statistical analysis, machine learning algorithms, or other analytical techniques are applied to identify patterns, correlations, and anomalies in the data. Descriptive analytics, diagnostic analytics, and predictive analytics methods are used to derive meaningful insights and generate forecasts. The models are refined and validated to ensure their accuracy and reliability. This phase involves iterative experimentation and testing to optimize the analytics models and techniques.
4. Phase 4: Integration and Deployment
   Once the data analysis and modeling phase is complete, the analytics results are integrated into actionable solutions and deployed for stakeholders' use. The insights, visualizations, and predictions are incorporated into decision-making processes and systems. The analytics outputs may be integrated with dashboards, reports, or interactive interfaces for easy consumption by stakeholders. The deployed solutions are tested for functionality, usability, and performance. User training and support materials are provided to ensure effective adoption and utilization of the analytics outputs.
5. Phase 5: Monitoring and Continuous Improvement
   After the deployment of the analytics solutions, the focus shifts to monitoring their performance, effectiveness, and impact on Covid-19 research and decision-making. Key metrics and indicators are tracked to assess the value and relevance

of the analytics outputs. Feedback from users and stakeholders is collected and analyzed to identify areas for improvement. Regular maintenance activities, including system updates, data refreshes, and bug fixes, are performed to ensure the accuracy and reliability of the analytics solutions. Continuous improvement efforts aim to enhance the analytics capabilities, adapt to evolving research requirements, and leverage new data sources or technologies.

Covid-19 Dataset from Our World in Data

The dataset is sourced from Our World in Data Websites, specifically the Coronavirus Pandemic Data Explorer (Our World in Data 2022). The dataset encompasses various attributes as outlined in Table 2.

Table 2 Covid-19 Dataset in Malaysia

Data Attribute	Data Description
Location_ID	Unique location ID
Location	Name of location
Date	Date of event
New cases	Number of new cases daily
Total cases	Number of accumulative cases
New Death	Number of new deaths daily
Total Death	Number of accumulative deaths

Covid-19 Descriptive Analytics and Visualization Framework

The Covid-19 Descriptive Analytics and Visualization framework refers to the structure that enables the analysis and visualization of data related to the Covid-19 pandemic, as shown in Figure 8. The framework incorporates descriptive analytics and visualization tools to extract meaningful insights and present them in a visually appealing and understandable manner. By employing this framework, researchers, policymakers, and the general public can gain valuable insights into the spread, impact, and trends of the Covid-19 virus, aiding in decision-making and resource allocation to combat the pandemic effectively.

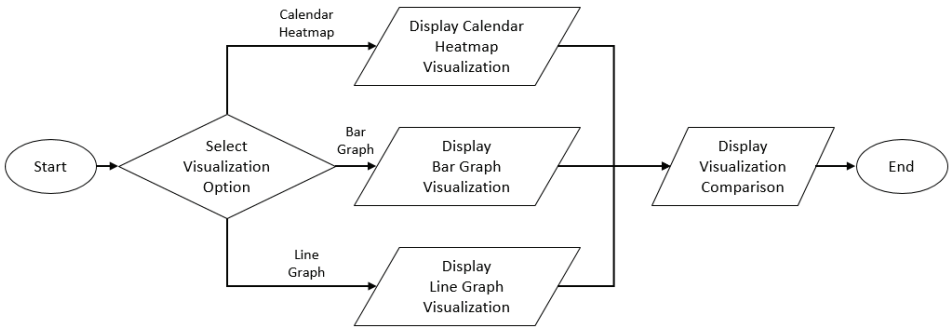

Figure 8 Covid-19 Data Visualization Framework

RESULTS AND DISCUSSION

The Covid-19 visualization approaches are implemented on a website that includes three primary types: calendar heatmap, bar chart, and line chart. Users have the flexibility to select the visualization type that best suits their needs and preferences.

Once users select their preferred visualization type, the system promptly generates and displays the chosen data visualization. This interactive feature allows users to engage with the data, explore trends, and derive insights specific to their interests. By presenting data in various visual formats, the website caters to different analytical needs and enhances the users' understanding of the Covid-19 situation.

The calendar heatmap visualization shown in Figure 9 specifically designed to showcase the daily cases and daily death cases related to Covid-19. This visualization provides a unique and comprehensive way for users to analyze and understand the impact of the pandemic over time. The Calendar Heatmap represents each day of a given time period as a separate cell or tile in a calendar-like grid. The cells are filled with colors that correspond to the intensity or magnitude of the Covid-19 cases or deaths for that particular day. This color-coded representation allows users to discern patterns and variations at a glance, as different colors indicate varying levels of intensity.

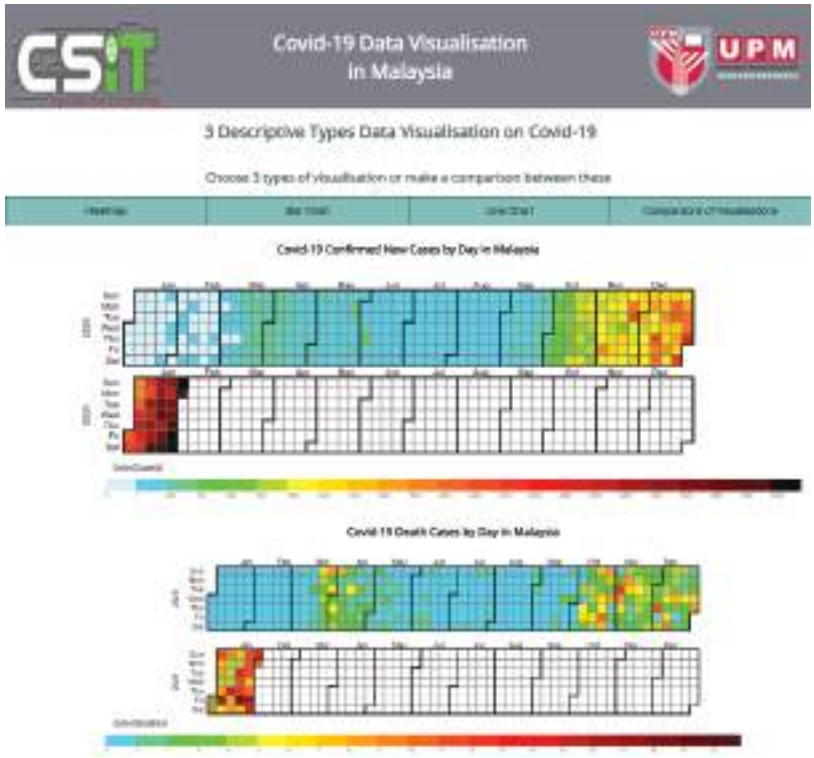

Figure 9 Result on Calendar Heatmap Visualization

The accuracy of the data values displayed in the calendar heatmap is of paramount importance. Users can trust that the data presented aligns with the latest and most reliable information available, ensuring the credibility of the visualization. This accuracy ensures that users can make informed interpretations and draw meaningful insights from the calendar heatmap.

By utilizing different colors to differentiate the intensity, the calendar heatmap effectively highlights the varying degrees of Covid-19 cases or deaths over time. This color differentiation allows users to identify hotspots, areas of concern, or regions with particularly high or low levels of infection or mortality. It helps to identify trends, patterns, and areas requiring focused attention or intervention.

Overall, the calendar heatmap visualization offers users a visually compelling and accurate representation of daily Covid-19 cases and deaths. It is able to facilitate the understanding of the pandemic's impact, supports data-driven decision-making, and enhances the communication of critical information related to the spread and severity of the virus.

The "Bar Graph" page as shown in Figure 10(a) offers a visual representation of daily cases and daily death cases using a bar graph. The bar graph visualization presents a visualization of daily cases and daily death cases through a bar graph. Users can accurately visualize the bar graph, where each bar represents the corresponding data value and distinguishes it from others. In this visualization, each bar corresponds to a specific data value and provides a clear distinction between different values.

Bar graphs are particularly effective in displaying discrete and categorical data, making them well-suited for representing Covid-19 statistics. Each bar in the graph represents a specific category, such as a specific date or location, and the length or height of the bar corresponds to the magnitude or count of the data value it represents. Users can accurately interpret the bar graph by observing the relative lengths or heights of the bars. This allows for easy comparison between different categories and helps identify patterns, trends, or significant variations in the data. For example, users can quickly identify which days had the highest number of cases or compare the number of deaths across different regions. Furthermore, the visual nature of the bar graph aids in the communication of data to a wide audience. It simplifies complex information, making it more accessible and understandable, even for individuals without a strong statistical or analytical background.

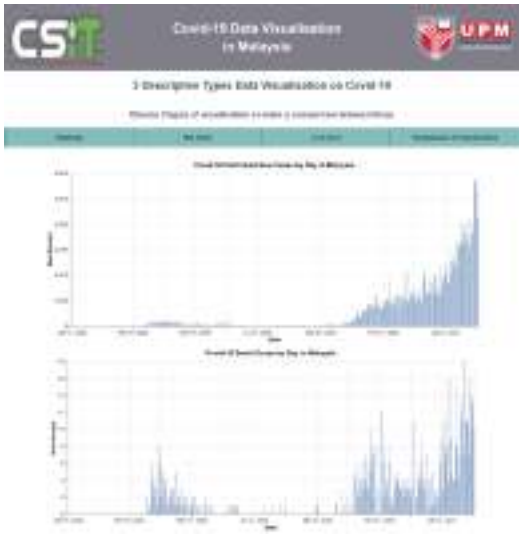

Figure 10 (a) Bar Graph Visualization

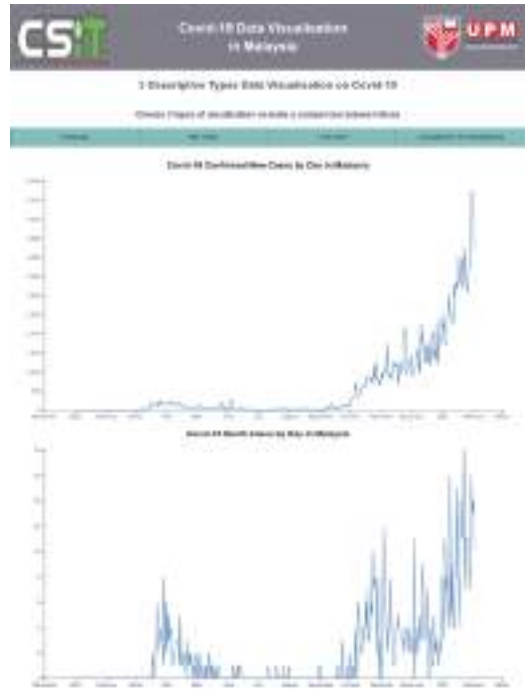

Figure 10 (b) Line Graph Visualization

The "Line Graph" page as shown in Figure 10(b) displays a visual representation of daily cases and daily death cases using a line graph. The line graph visualization presents a line graph representing daily cases and daily death cases. Users can visualize the line graph with accurate data values, and the line differentiates the values over time. This type of visualization is particularly effective in illustrating trends and changes over time. In the line graph, each data point is represented by a marker, and these markers are connected by a line, creating a continuous visual representation of the data over a specific time period. The vertical axis typically represents the number of cases or deaths, while the horizontal axis represents the progression of time, such as days, weeks, or months.

By plotting the data points and connecting them with a line, the line graph provides a clear depiction of the fluctuation and progression of daily cases and deaths over time. This enables users to visualize the rise or fall of the numbers, identify peak periods, and observe any significant patterns or trends. Users can accurately interpret the line graph by examining the position of the line at specific time points. The line graph distinguishes the values by the slope, height, or position of the line relative to the axis. For example, an upward or downward slope indicates an increase or decrease in cases or deaths, respectively.

The line graph's ability to showcase temporal patterns and changes makes it valuable for tracking the progression of the pandemic, assessing the effectiveness of

interventions, and identifying potential turning points. By visualizing the data with accuracy, users can gain insights into the impact of the virus over time and make informed decisions based on the observed trends.

Discussion on the Comparison of Calendar Heatmap, Bar Chart and Line Chart Visualization of Covid-19 Dataset

The calendar heatmap visualization stands out with its ability to provide an intuitive and comprehensive overview of the data. It typically uses colors to represent the intensity or magnitude of a particular variable, allowing users to quickly identify patterns and variations in the data. Calendar heatmaps are especially useful for representing large datasets or time series data, as they condense information into a visual grid format. In contrast, a bar chart is effective in displaying discrete and categorical data. It uses vertical or horizontal bars to represent different categories and their corresponding values. Bar charts are particularly useful for comparing values among different categories and identifying the highest or lowest values. They provide a clear visual distinction between data points and allow for easy comparison. On the other hand, a line chart is ideal for representing trends and changes over time. It connects data points with lines, enabling users to observe patterns, fluctuations, and relationships between variables. Line charts are commonly used to analyze time series data, such as tracking the progression of Covid-19 cases over weeks or months.

While all three visualization methods serve different purposes, the calendar heatmap stands out due to its ability to provide an intuitive and comprehensive overview of data by utilizing colors to represent intensity or magnitude. It condenses information and allows users to quickly identify patterns and variations in the data. The comparison of calendar heatmap, bar chart and line chart is shown in Figure 11.

The calendar heatmap is a powerful visualization technique that effectively presents data in a grid-like format. It utilizes colors to represent the magnitude, intensity, or density of a particular variable across different categories or time periods. The key advantage of a calendar heatmap is its ability to provide a quick and holistic understanding of data patterns. By using a color spectrum, it allows users to easily identify areas of high or low values, patterns, and outliers. This is especially valuable when working with large datasets or when exploring complex relationships between multiple variables.

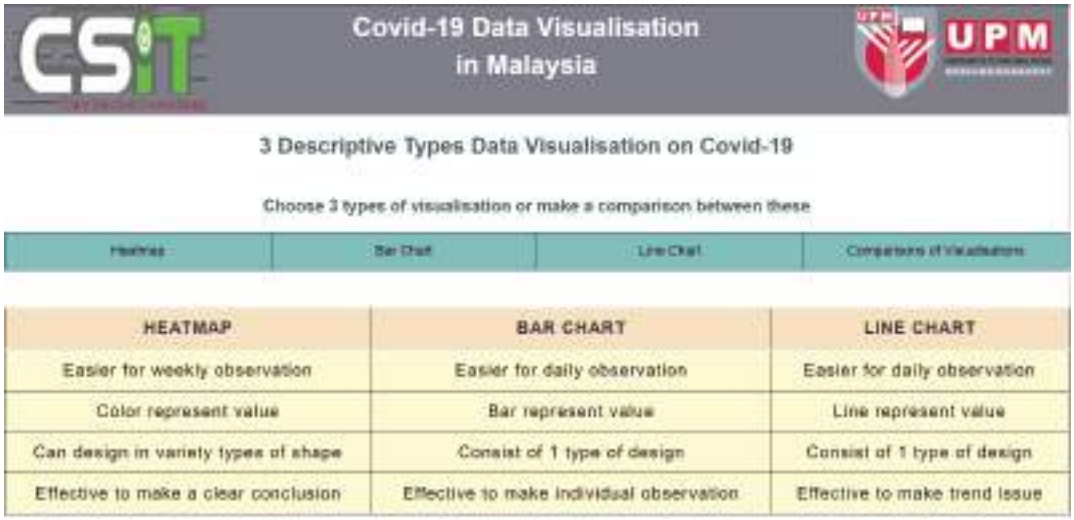

Figure 11 Result on Display (Comparisons of Visualizations)

CONCLUSION AND FUTURE WORKS

A Covid-19 descriptive visualization approach is proposed by highlighting calendar heatmap visualization and its achievements, weaknesses, and areas for future improvement. The objective of the approach was to design a comprehensive computer-based platform that offers multiple data visualizations for tracking Covid-19 cases in Malaysia.

One significant achievement of the Covid-19 Data Visualization approach was the creation of a descriptive analytics tool that effectively communicates the daily Covid-19 cases and associated death rates in Malaysia. By offering calendar heatmap visualization approach, the current state of the pandemic is successfully conveyed and able to provide valuable insights. Calendar heatmaps are commonly used in various fields, including data analysis, finance, biology, and, in the case of Covid-19, epidemiology. In the context of the Covid-19 pandemic, a calendar heatmap can visually represent the intensity of daily cases, deaths, or other relevant metrics across regions or time periods. This helps in identifying hotspots, trend variations, or correlations between factors.

However, it is important to note that the Covid-19 Data Visualization approach has limitations. One notable weakness is its inability to capture and display the important dates and factors influencing the trends of Covid-19 cases, such as the impact of significant events or interventions. For instance, the system fails to represent the effectiveness of measures like the Movement Control Order implemented on March 18th, 2020, which significantly contributed to the reduction in cases.

For future work, the approach can be improved by focusing on incorporating important dates and contextual factors that influence the Covid-19 case trends. It would provide a more comprehensive understanding of the underlying dynamics and facilitate better decision-making for stakeholders involved in pandemic management. Several future enhancements and improvements that can done on Covid-19 Data Visualization to provide better features to users:

1. Adding several attributes - Attributes like number of testing, numbers of recoveries, number of senior citizens, number of bedrooms and many more will help user on making analysis.
2. Diagnostic Analytics - Extra features like link the system with news on the important dates, this will explain on why the data can be like that and help users to planning for their next moves on handling this pandemic.
3. Predictive Analytics - several Machine Learning models can be implemented and predictive analytics can be done. This will give more assistant on visualization on what happen if user keeps do nothing with this issues.

In conclusion, the calendar heatmap visualization approach has been shown to be a valuable tool for visualizing and analyzing COVID-19 cases in Malaysia. It successfully captures the general trends of the pandemic, but it could be further enhanced to contribute significantly to the understanding and management of the pandemic. The proposed approach can also be used to visualize other types of pandemics, such as the spread of influenza or HIV/AIDS. The suggested improvements are targeted at providing a more comprehensive understanding of the underlying dynamics and facilitating better decision-making for stakeholders involved in pandemic management.

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