Visual Analytics approach on Global Life Expectancy

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Abstract— This visual analytics project delves into global life expectancy trends from 1950 to 2021, unraveling insights through various temporal, spatial, and gender analyses. Leveraging diverse visualizations, including temporal graphs, heatmaps, and area plots, the study navigates shifts in life expectancies, aligning them with historical events. Key findings showcase a global surge in life expectancy, nuanced gender disparities, and notable patterns in age-specific life expectancies. The analysis extends to the impact of significant events, such as the HIV/AIDS epidemic and the COVID-19 pandemic, shedding light on regional resilience and vulnerability. The role of human reasoning in interpreting intricate patterns is emphasized. Despite limitations like data granularity and the absence of geographical specifics, the project underscores the importance of transparent decision-making in visual analytics. Future work could explore in-depth analyses of outlier regions and leverage advanced visual analytic tools for enhanced insights.

1 Problem Statement

Since 1990, global life expectancy has experienced a remarkable surge, increasing by over seven years, equivalent to gaining a year every three-and-a-half years [1]. This analysis dives deep into the extensive evolution of global life expectancy from 1950 to 2021, encompassing both genders across all age groups (0 to 100+). Using datasets from the United Nations World Population Prospects (UNWPP) [2], which detail life expectancy at exact ages for females, males, and both genders, the analysis embarks on a journey to address fundamental questions.

The analysis seeks to answer the following questions:

- How has global life expectancy shifted from 1950 to 2021, and do these changes align with significant events or distinct periods?
- What intricacies exist in gender disparities globally and within specific regions, and are there regions where the gender gap in life expectancy has undergone extreme changes?
- What are the discernible patterns in life expectancy at birth (age 0) and during the transition to older adulthood (age 60) on a global scale?

In 2019, the world underwent profound changes marked by a rising death toll, prompting a plausible impact on global life expectancies [3].

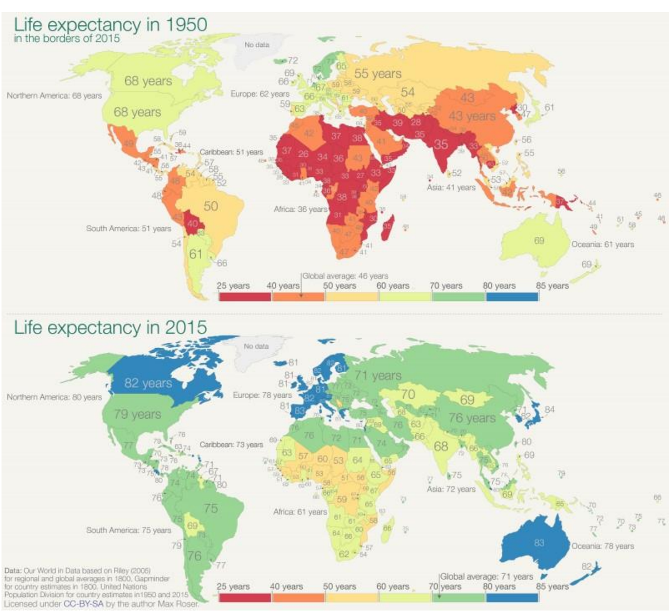
Our main aim is to explore the repercussions of such global events on life expectancies worldwide and identify regions that exhibited resilience or vulnerability to these impactful occurrences.

The richness and granularity of the datasets employed are instrumental in unravelling nuanced patterns, facilitating a more detailed and accurate exploration to address the analytical questions at hand.

2 State of the Art

In Andrew J. Scott's research paper and conference [4,5], the exploration extends beyond the increase in life expectancy, delving into both positive and negative implications over the years. The analysis is keen on visualizing outcomes and emphasizes the intersection of aging and health, considering the sustainability of the world population. It examines the far-reaching impacts of longevity on various sectors, including the economic, political and financial sectors. Scott also addresses the potential drawbacks of this, such as a reduced working-age population, lower GDP, and increased health and pension expenditures. The datasets used for the research are from UN Department of Economic and Social Affairs and the United Nations World Population Prospects. This comprehensive approach aligns with the multifaceted nature of our analysis, allowing for a nuanced exploration of global longevity and health. His lecture on the emphasis on sustainability and its intertwining with world population dynamics resonates with our goal of understanding the resilience or vulnerability of regions to global events. While Scott's research underscores the importance of healthy longevity, our project is primarily based on examining life expectancy trends using visuals in relation to global events, age and gender roles, and regional resilience. However, we can draw inspiration from Scott's comprehensive approach to data analysis and visualization to enrich the depth of our exploration. The visuals created in Scott's exploration of UN projections for life expectancies until 2100 provides a forward-looking perspective, offering a potential benchmark for our analysis of long-term trends in our dataset. In summary, even though there isn't a strong resonance between the key themes in Scott's work and the objectives of our project, learning from his in-depth analysis and visualizations, we can enrich our understanding of the complex interplay between global events, socioeconomic factors, and longevity.

F. Baum *et al.* [6] introduces an insightful research paper focusing on gendered life expectancy differences (GLED) and providing a complex understanding of the reasons behind disparities between genders globally. The study employs a



Graph taken from Max Roser [7] (a)

distinctive combination of epidemiological and sociological methods, with the help of impactful visualizations. The paper confirms the persistence of GLED across the world and looks into specific cases in Australia and Ethiopia. The datasets utilized, sourced from reputable institutions such as the World Bank and UNICEF, add accuracy to the analysis. The paper not only visualizes GLED comprehensively but also offers a deep exploration of the complex factors contributing to gender-based differences in life expectancy. This aligns seamlessly with the objectives of our project, where we seek to visually represent and understand the disparities between the genders' life expectancy. This work not only serves as a valuable reference with good visuals, but transforms our assumptions into substantiated insights, providing clarity on why women globally tend to outlive men.

A supplementary source worth mentioning is Max Roser's [7] article, providing additional insights into global life expectancy trends over time. Utilizing a dataset similar to ours from UNWPP, Roser's work showcases visually appealing representations comparing how life expectancies have evolved globally from 1950 to 2015 (graph shown above (a)).

3 Properties of the Data

The datasets used in this task are taken from the United Nation World Population Prospects 2022 from the data portal of the original website [2]. There are 3 different datasets showing the life expectancy rates of females, males and both the genders globally from the years 1950 to 2021 for the age groups from 0 to 100. The datasets are described as 'The average number of remaining years of life expected by a hypothetical cohort of males/females/both sexes alive at age x who would be subject during the remaining of their lives to the mortality rates of a given year. It is expressed as years.' [2] The United Nations World Population Prospects (UNWPP) gathers data by combining information from national population censuses, vital registration systems, and nationally representative sample surveys. Covering 237 countries or areas, the UNWPP provides insights into global population dynamics from 1950 to the present.

Upon examination, each dataset showcased a shape of (20524, 109), where 100 columns captured life expectancy at each age. Additional columns provided geographical and temporal information, including 'Regions, Subregions, Countries and areas', 'Variant', 'Index', 'SDMX code', 'Type', 'location code', 'parent code', and 'Year'. However, given the analytical focus on geographical regions and the impact of global events on life expectancy, a meticulous data cleansing process was initiated. Unnecessary columns like 'Index' and 'SDMX code' were dropped, and irrelevant rows under the 'Type' column, labelled as Label/Separator, representing Sustainable Development Goal Regions, UN Development Groups, World Bank Income Groups, and Geographical regions, were eliminated. The refined dataset retained only the essential geographical regions, with the 'Type' column values encompassing World, Region, Subregions, and countries. Further reshaping of the dataset employed the (.melt) function, creating distinct columns for life expectancy among females, males, and both sexes. This resulted in a streamlined dataset with a shape of (201600, 10).

Despite some limitations in the precision of geographical regions (given names without latitude or longitude) and temporal data (only the year without month or day information), the refined dataset is well-suited for the project's overall goals of exploring global life expectancy trends. Furthermore, to understand the tidy dataset, several visuals were created to see the distributions of the important columns.

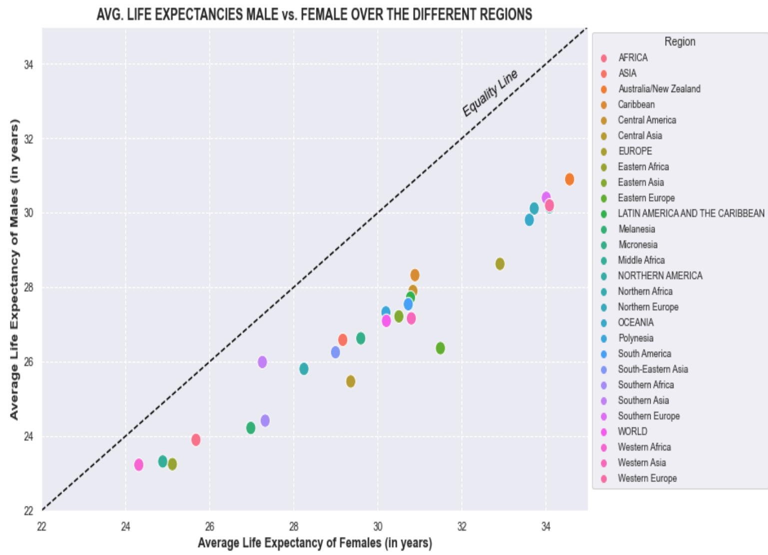


Fig 1

In Figure 1's scatter plot, we compare average life expectancies of females (x-axis) and males (y-axis) across different regions. All regions lie below the equatorial line, affirming F. Baum *et al.*'s [6] findings that, on a global scale, females generally outlive males. Distances from the equatorial line vary, revealing varying gender gaps in life expectancies across regions.

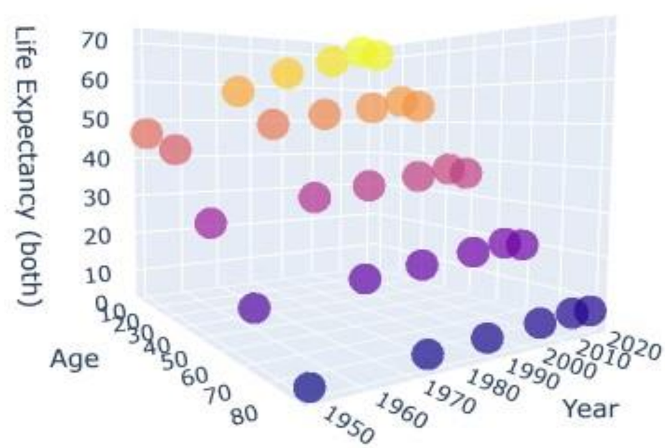


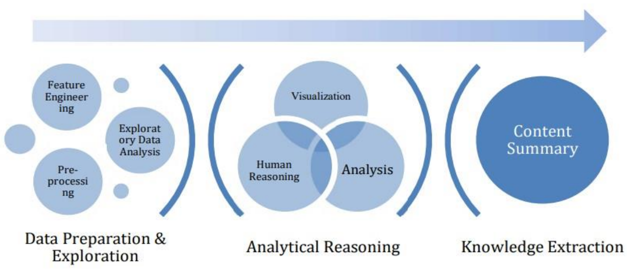
Fig 2: LifeExpectancy3D: Temporal and Age Exploration

The 3D model (fig 2) illustrates life expectancy trends for both genders combined from 1950 to 2021, focusing on ages 0 to 90. Generally, life expectancy is higher at younger ages. For each respective age group, there is a continuous upward trend in life expectancy as we advance towards more recent years. However, a closer look shows a slight dip between 2010 and 2020, possibly linked to the impact of the Covid-19 pandemic in 2019.

4 ANALYSIS

4.1 Approach

To tackle the research questions, I'll use a visual analytics approach, merging computational tools like Tableau and Python with human insight. Utilizing Tableau's simplicity for visualizations and Python for in-depth analysis, I aim to extract insights from both overall and region-specific life expectancy data. Considering the potential pitfalls of aggregate data, I carefully explored individual observations by visualizing life expectancy across years, age groups, and regions. The primary focus is on understanding the impact of global events on different aspects of the dataset. This involves a thorough examination of temporal, spatial, and gender-specific patterns, aiming to uncover the intricate dynamics between external factors and life expectancy trends. This balanced computational and human-centric approach is designed for a nuanced exploration of the life expectancy dataset. Presented is a streamlined flowchart depicting the key steps in our analysis approach.



Basic Analysis Approach flow chart (b)

A] Temporal Approach Steps:

1) Identifying Long-term Trends: Employing line graphs and time series visualizations to discern overarching trends in life expectancy from 1950 to 2021.
2) Comparison Across Genders: Contrasting trends for males and females to identify temporal variations in life expectancy between genders.
3) Regional Temporal Patterns: Exploring variations in temporal patterns across different regions, visualizing life expectancy trends over time in diverse geographical areas.

The aim of this analysis approach is investigating specific events or periods influencing global life expectancy, discerning temporal patterns around major occurrences.

B] Spatial Approach Steps:

1) Detailed Spatial Analysis: Using heatmaps with latitude and longitude values (added manually) to highlight regions with varying life expectancies, examining specific years. Considering topographical and regional characteristics to explain variations in life expectancy globally. Applying clustering techniques may not be necessary as the focus is on regions and subregions, clearly depicted by the geographical heatmap.

C] Gender Gap Approach Steps:

1) Temporal and Spatial Gender Analysis: Examining how gender-specific life expectancy patterns change over time and across different geographical regions, identifying periods of widening or narrowing gaps.
2) Age-specific Gender Trends: Analyzing gender-specific trends for different age groups to identify contributions to the overall gender gap.

These steps pave the way for a nuanced analysis of life expectancy changes amid global events, offering a more precise exploration of their impact across diverse dimensions.
Human interpretation and reasonings play a crucial role in our analysis, especially when dealing with life expectancies and global events. Consulting the experts to get valuable insights and deep knowledge will help make sense of the complexities involved. Algorithms excel at pinpointing correlations, but unraveling causation often demands human reasoning and understanding, especially when comprehending regional intricacies like the persistent low life expectancy in Africa. This is vital for spotting anomalies, considering ethical aspects, and understanding the intricate relationships between different factors. While algorithms provide statistical insights, it's the human touch that ensures a holistic and meaningful interpretation, keeping our analysis grounded in the real-world context.

4.2 Process

Prior to delving into the analysis, a comprehensive exploration of the correlation between life expectancy across years and regions with the help of a heatmap was conducted. This preliminary step aimed to identify significant changes in life expectancies, laying the foundation for our analysis.
To generate this heatmap, a correlation matrix is calculated based on the life expectancy values for different years and regions, each row corresponding to a distinct region, and

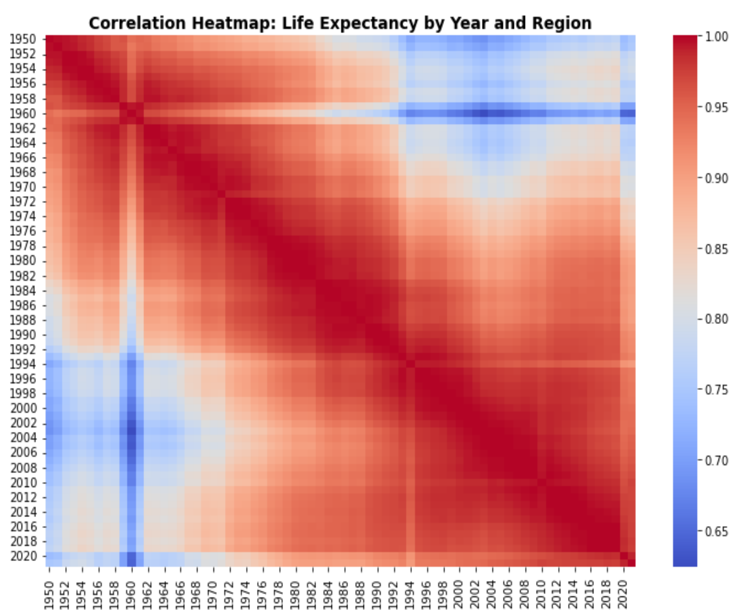


Fig 3

columns representing different years. The color intensity is kept such that the warm colors show a positive correlation while the cool colors indicate a negative correlation. While the y-axis does not explicitly label regions for visual clarity, the interpretation involves understanding that each row represents a unique geographic entity, providing insights into the correlation patterns across time and regions. Upon examining the heatmap, a distinct shift around the year 1960 becomes evident, indicating substantial changes in life expectancy correlations across years and regions. This noteworthy transformation aligns with a significant historical event, namely the World's largest famine, which unfolded in East Asia, particularly in China, between the spring of 1959 and the end of 1961. During this period, an estimated 70 million Chinese individuals tragically succumbed to starvation [8]. The ripple effect of this catastrophic event is prominently reflected in the global drop in life expectancy correlations during the years 1959 to 1961. Similarly, a comparable effect is seen around 2019, attributed to the global impact of the COVID-19 pandemic. The associated rise in mortality rates worldwide resulted in a substantial decline in life expectancy correlations. Another pivotal shift appears in 1994, marked by the Rwandan genocide in Central Africa, where approximately 800,000 lives were lost [9]. This interpretation accentuates the indispensable role of human insight and historical knowledge in recognizing and comprehending changes observed in the heatmap, leaving an enduring impact on life expectancy trends.

Transitioning to the analysis phase outlined in our approach, we delve into the dataset through visual exploration, seeking deeper insights to address our analytical questions

A] Temporal Analysis

1) Identifying long-term trends based on the regions:

The temporal graph depicted in Fig 4 unfolds the narrative of average life expectancy spanning from 1950 to 2021, providing a comprehensive response to the first analytical question. The graph portrays a remarkable global surge in average life expectancy, nearly doubling since the 1900s. In 1950, richer regions like Oceania, Northern America, and Europe had much higher life expectancies than Asia and Africa, which were more populated and less developed. Over the years, countries worldwide caught up, thanks to development and improved healthcare. Despite encountering various events, regions managed to bridge the gaps. An exception to this is Africa, where persistent challenges like poverty, hunger, and illness contribute to consistently lower life expectancies [10]. Notably, Africa witnessed a modest rise in life expectancy from 1950 to 1990, followed by a decline or stagnation from 1990 to the early 2000s, attributed to the devastating HIV/AIDS epidemic in sub-Saharan Africa, affecting approximately 60 million people and claiming an estimated 20 million lives [11]. The average life expectancy in Europe and Northern America experienced a modest decline during the 1990s to the early 2000s, influenced in part by the HIV/AIDS epidemic [13]. As the Chinese famine affected Asia's

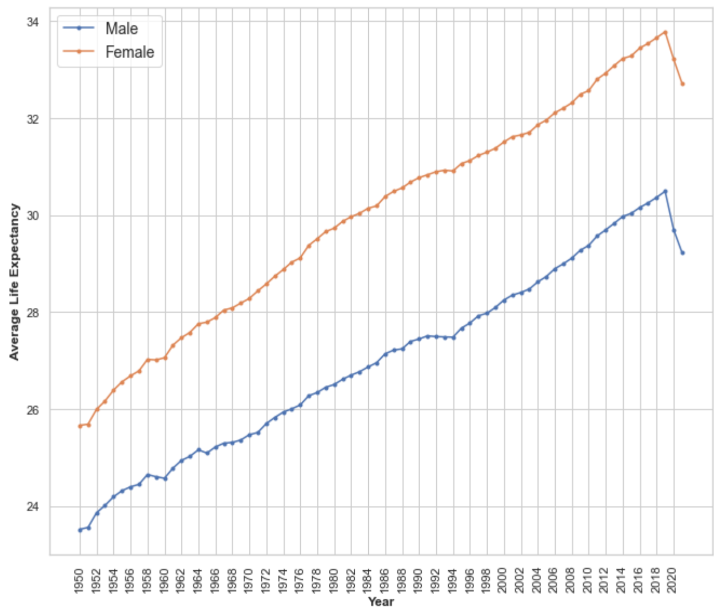
Fig 4: Average Life Expectancy over the years in different Regions

average life expectancy in 1960, it also affected the World's average life expectancy.[8] In the temporal graph, a noticeable drop in average life expectancies is evident across almost all regions from 2019. This decline is directly linked to the global impact of the Covid-19 pandemic and the lives it claimed. Interestingly, Oceania stands as an exception, resisting the overall downward trend. This resilience can be attributed to the fact that, despite the presence of the Covid-19 outbreak in Oceania, ten sovereign states in the region have not reported a single case, showcasing a unique scenario [12].

To summarize, the graph not only chronicles the global life expectancy shift from 1950 to 2021 but also illuminates the alignment of these changes with significant events or distinct periods, thus answering the first analytical question. Human reasoning played a pivotal role in comprehending the historical context, explaining anomalies, and delving into the nuanced implications of various events and ethics, thus enriching the interpretation of the temporal trends.

2) <u>Comparison across genders:</u>

Fig 5: Average Life Expectancies of Males and Females over the years



In Fig 5, the temporal graph visualizes the average life expectancies of males and females from 1950 to 2021. The graph portrays a consistent linear increase in the average life expectancy for both genders over the years. As proved by F. Baum *et al.* [6], the male average maintains a trend of lower life expectancy as compared to females. Notably, both sexes experience a parallel decline in life expectancy from 2019, attributed to the impact of the Covid-19 pandemic.

3) <u>Regional Temporal patterns:</u>

The geographical heatmap (Fig 6) serves as a compelling visual testament to the global rise in average life expectancies. In 1950, the map exhibits low color intensity, indicative of lower life expectancies. As we progress to 2021, there's a noticeable surge in color intensity, particularly in Asian regions, Oceania, and other areas, signifying a substantial improvement in average life expectancies. While the visual patterns provide valuable insights, the nuanced understanding of regional disparities and the impact of various factors demands human interpretation. This human involvement ensures a comprehensive analysis that goes beyond statistical observations, considering socio-economic and cultural nuances that contribute to these trends. Notably, Western Africa displays minimal change, consistent with earlier observations, emphasizing the significance of human insight in interpreting the heatmap's intricate patterns.

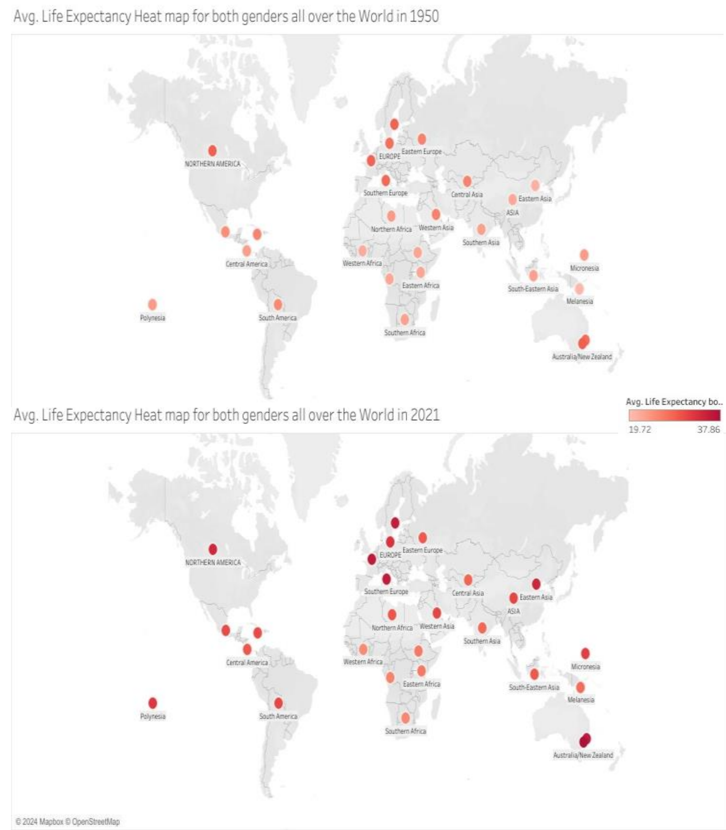


Fig 6: Comparative Geographical Heatmap showing the life expectancies around the world in the year 1950 and 2021

B] Spatial Analysis:

1) <u>Detailed Spatial Analysis:</u>

For a detailed spatial analysis, along with the analysis of the heat map for regional temporal patterns (fig 6), an area plot is created showing the percentage increase in the life expectancy for major regions over the years. The plot is shown in fig 7.

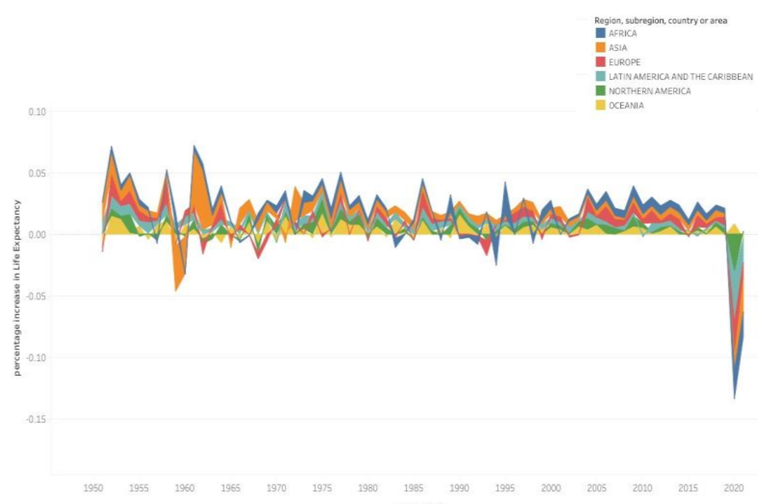


Fig 7: Percentage increase in life expectancy for all the regions over the years

The calculated percentages offer a valuable metric for assessing the dynamic shifts in life expectancy over time, with colors representing different continents. A notable drop in the percentage of life expectancy is evident for Asia from 1959 to 1961 (-0.042%), attributed to the tragic Chinese Famine. Similarly, Africa sees a decline in 1960, likely due to the Yellow Fever outbreak in Ethiopia from 1960 to 1962[14]. The spike in negativity for Africa in 1994 aligns with the devastating Rwandan genocide [9]. Particularly striking are the pronounced spikes in percentage change for Africa, indicating significant fluctuations in life expectancy. The reasons behind Europe's negative spike around 1966 remain unclear, but the dip in 1992, alongside Northern America, is attributed to the HIV/AIDS breakout [13]. The recent pandemic after 2019 brings a universal negative shift in percentage change, except for Oceania (in yellow). Oceania's resistance to this trend could be attributed to lower population density and effective management of COVID-19 in Australia and New Zealand. Also, ten sovereign states in Oceania reported zero COVID-19 cases[12], underscoring the uniqueness of this scenario and highlighting the importance of human reasoning in interpreting such intricate regional variations.

C] Gender Analysis:

1) Temporal and Spatial Analysis:

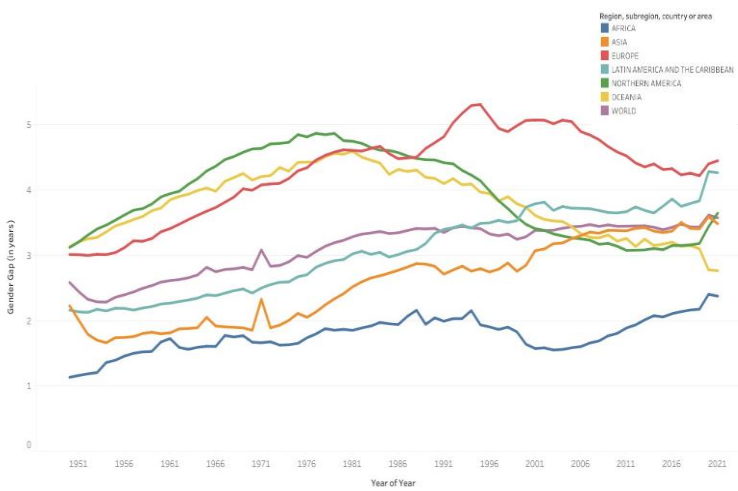


Fig 8: Line chart illustrating the Gender gap all around the world over the years

This line chart illustrates the gender gap in life expectancy across different regions, calculated by subtracting the average life expectancy of males from females over the years. Notably, Africa exhibits the smallest gender gap. A spike in the gender gap is observed in Asia in 1971. This can be attributed to the Indo-Pakistan war in South Asia, which resulted in a significant loss of male lives [13]. Oceania and Northern America show drops in gender gap life expectancy, while Europe experienced a major rise after 1993 for an unclear reason. The intricate patterns suggest the influence of historical events on gender gap trends. Human insight is crucial here to interpret the socio-political contexts and complexities surrounding each region's unique circumstances, shedding light on the nuanced dynamics shaping gender gap shifts in life expectancy. In summary, this analysis, guided by human interpretation, provides insights into regional variations in the gender gap, addressing our second analytical question. Importantly, no regions can be seen to have undergone extreme changes in gender disparities over the years.

2) Age-Specific Gender Analysis:

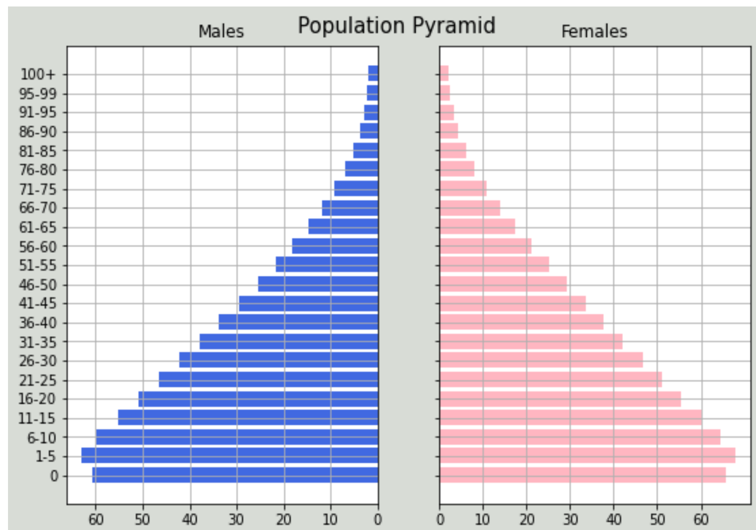
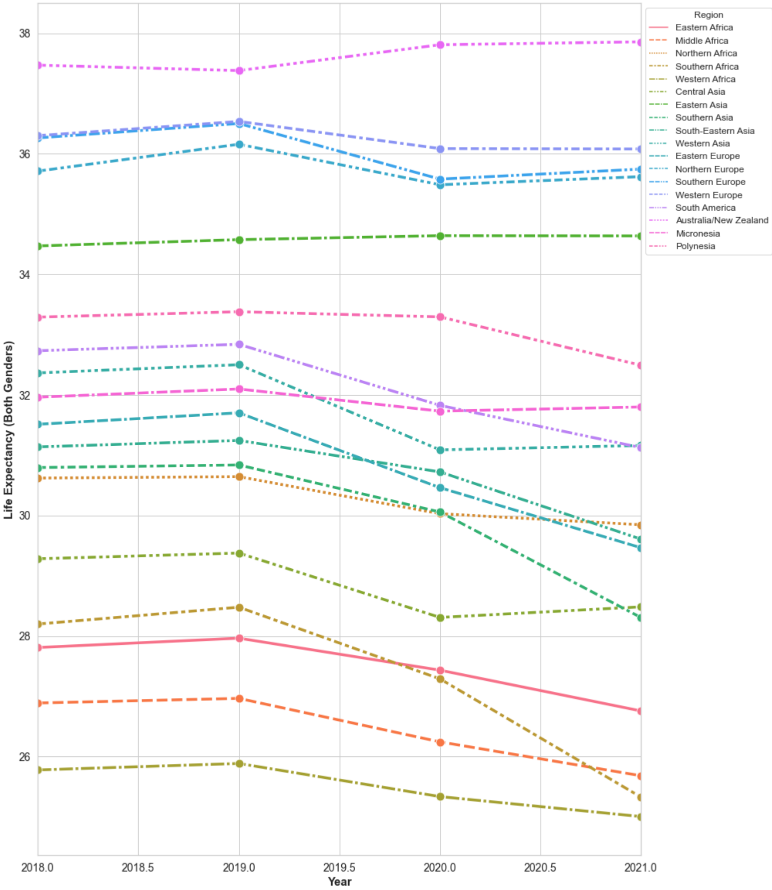


Fig 9

The population pyramid in Figure 9 illustrates the average life expectancy of males in blue and females in pink across different age groups. A notable trend is the lower life expectancy at birth compared to subsequent age groups. This phenomenon is often observed in less-developed countries, where high infant mortality rates, often due to infectious diseases or inadequate access to clean water, contribute to lower life expectancy at birth [16]. This pyramid underscores that average female life expectancy exceeds that of males across all age groups. As individuals transition to older age, particularly after 60, there is a natural decline in average life expectancy for both genders. These patterns offer insights into the dynamics of life expectancy at birth and during the transition to older adulthood on a global scale, thus answering our third analytical question.

4.3 Results

To delve deeper into our primary analysis, we focused on the years of the COVID-19 pandemic (2019 to 2021) using a temporal chart for sub-regions. Fig. 10 revealed varying responses, with most regions experiencing a decline in average life expectancy. Notable exceptions were Australia and New Zealand in Oceania, which not only showed resilience, but also depicted a positive growth in the average life expectancy, Fig 10: Temporal Chart showing the effects of Covid-19 Pandemic on the subregions



which can be attributed to effective pandemic management based on science and empathy, particularly in New Zealand[17]. Surprisingly, Eastern Asia also demonstrated resilience. Conversely, Southern Africa emerged as the most vulnerable, witnessing a substantial drop in life expectancy from 28.5 in 2019 to 25.3 in 2021.

In summary, our analysis reveals a continuous global rise in life expectancy from 1950 to 2021, marked by subtle shifts linked to significant world events. Fig. 8 delves into gender gap intricacies, offering a nuanced exploration of male and female life expectancies. Meanwhile, Fig. 9 sheds light on discernible patterns, unravelling the lower life expectancy at birth compared to subsequent age groups during the journey to older adulthood. Detailed discussions on the repercussions of the COVID-19 pandemic and other global events further enrich our understanding, emphasizing the importance of tailored interventions and informed policymaking in global health.

5 Critical Reflection

A] Thought Process and role of visual representations:

With the focus on exploration of life expectancies throughout the years from 1950 to 2021 globally, analytical approach was shaped in a strategic way to employ the visual representations to unravel intricate patterns in data.

The initial heatmap analysis served as a foundational step, visually highlighting correlations between life expectancy, years, and regions. This informed subsequent decisions, steering the course of the analysis towards meaningful insights.

The choice of temporal analyses, utilizing line graphs, facilitated a comprehensive understanding of long-term trends and the impact of major global events on life expectancies. Incorporating existing research findings, as evidenced in the temporal gender comparison, enriched the analysis, showcasing a critical fusion of visual and academic insights. The spatial analysis, particularly the interpretation of heatmaps and percentage change graphs, demonstrated the necessity of human reasoning to unravel nuanced regional variations and exceptions. Integrating a gender-focused and age-specific analysis, with the help of population pyramid further underscored the importance of thoughtful visualizations in addressing specific analytical questions. The detailed timeline chart from 2018 to 2021, focusing on COVID-19's impact on subregions, greatly enhanced our analysis. It helped us understand how different areas coped with the pandemic's effects on life expectancy.

Overall, the strategic use of visual representations was pivotal in navigating the complexity of the dataset, allowing for a nuanced exploration of global life expectancy trends and facilitating a comprehensive interpretation of historical and demographic influences on the data.

B] Limitations of the Analytical approach:

The integration of advanced visual analytic tools, such as V-Analytics, could significantly enhance the depth and insights derived from geographical heatmaps during spatial analysis. However, the absence of latitude and longitude values in our dataset limited the utilization of these sophisticated tools. The inclusion of such geospatial information would offer a more detailed and comprehensive exploration of global life expectancy patterns across regions.

Another limitation in our analysis lies in the removal of detailed geographical data, including information about areas and cities, due to the dataset's large size. While the decision was practical for addressing specific analytical questions and managing the dataset's scale, it restricted our ability to delve into more localized factors influencing life expectancy. Therefore, the analysis focused on broader regional trends, overlooking potential insights that could have been gained from examining specific cities or areas.

C] Potential future works:

While our analysis hinted at intriguing exceptions in regions like Africa and Oceania, a more focused and in-depth exploration of these areas remains an open avenue for future research. Understanding why these regions exhibit unique trends in life expectancy could unveil valuable insights. Future work should consider delving deeper into the socio-economic, cultural, and healthcare dynamics of these regions. Additionally, employing advanced visual analytic tools, such as V-Analytics and Orange, could enhance the depth and precision of the analysis, provided relevant geographical data is available. Researchers must transparently acknowledge the limitations and trade-offs in their analytical decisions, emphasizing the need for a balanced approach that doesn't solely rely on visual representations. This ensures a more robust and nuanced exploration of the data while maintaining methodological integrity.

TABLE OF WORD COUNTS

Problem statement	240
State of the art	499
Properties of the data	492
Analysis: Approach	467
Analysis: Process	1466
Analysis: Results	208
Critical reflection	509
Total (excl. abstract)	3881

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