Looking at COVID-19 Data

This notebook will show you:

1. How to make simple charts using tools like Matplotlib and Seaborn
2. How charts can sometimes be tricky and how to make them clearer
3. A small project using COVID-19 data to tell a story

Exploring Global Health Insights: A Look at COVID-19 Data

This notebook delves into the COVID-19 dataset to illustrate key data visualization techniques and storytelling principles. We will cover:

1. Crafting clear and informative charts using Python libraries like Matplotlib and Seaborn.
2. Understanding how chart design choices can impact interpretation and how to avoid misleading visuals.
3. A practical project using real-world COVID-19 data to demonstrate data-driven storytelling.

1. Fundamental Visualizations

Let's start by exploring some basic charts to understand the initial trends in the data.

2. Recognizing Potential for Misinterpretation in Visualizations

This section highlights how subtle changes in chart design can lead to misleading conclusions, emphasizing the importance of careful visualization choices.

3. Storytelling with COVID-19 Dataset

Here, we will apply our visualization skills to tell a story using the COVID-19 data, combining different perspectives to gain deeper insights.

> ### Leveraging Streamlit

This section introduces how to build interactive web applications for data exploration using Streamlit.

```
!curl -o country_wise_latest.csv "https://files.vxrachit.is-a.dev/datasets/country_wise_latest.csv"
```

```
  % Total    % Received % Xferd  Average Speed   Time    Time     Time  Current
                                 Dload  Upload   Total   Spent    Left  Speed
100 14596    0 14596    0     0  39396      0 --:--:-- --:--:-- --:--:-- 39448
```

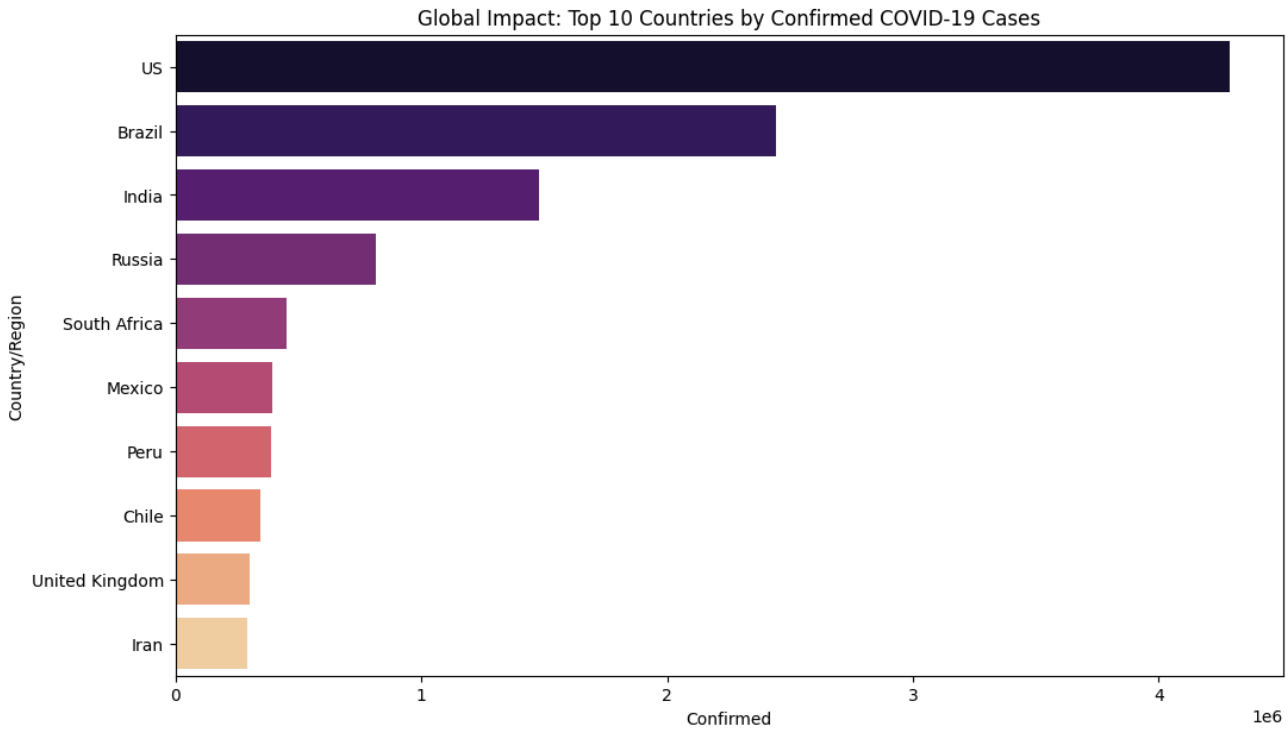
```
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns

df = pd.read_csv('country_wise_latest.csv')
display(df.head())
```

	Country/Region	Confirmed	Deaths	Recovered	Active	New cases	New deaths	New recovered	Deaths / 100 Cases	Recovered / 100 Cases	Deaths / 100 Recovered	Confirmed last week	1 we chan
0	Afghanistan	36263	1269	25198	9796	106	10	18	3.50	69.49	5.04	35526	7
1	Albania	4880	144	2745	1991	117	6	63	2.95	56.25	5.25	4171	7
2	Algeria	27973	1163	18837	7973	616	8	749	4.16	67.34	6.17	23691	42
3	Andorra	907	52	803	52	10	0	0	5.73	88.53	6.48	884	
4	Angola	950	41	242	667	18	1	0	4.32	25.47	16.94	749	2

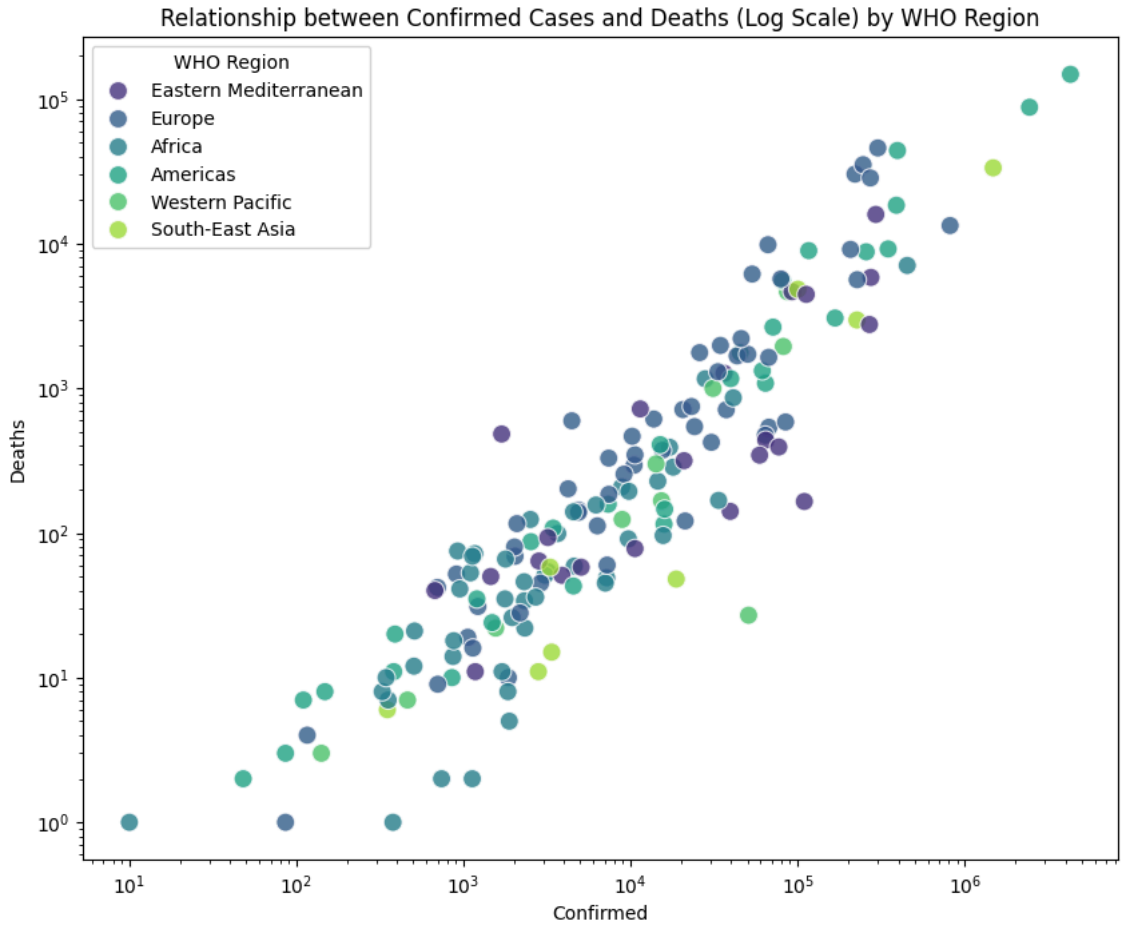
1. Basic Visualizations

```
top10 = df.nlargest(10, 'Confirmed')
plt.figure(figsize=(12,7))
```

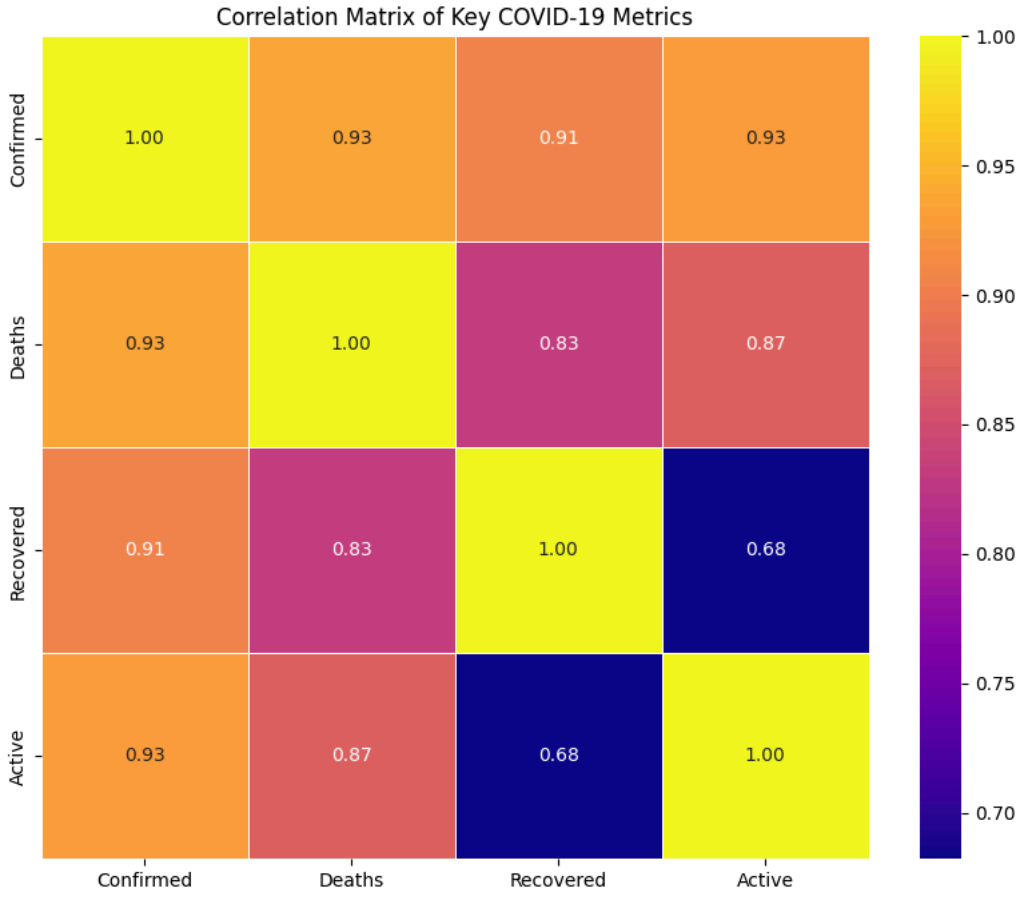
```
sns.barplot(x='Confirmed', y='Country/Region', data=top10, palette='magma', hue='Country/Region', legend=False)
plt.title('Global Impact: Top 10 Countries by Confirmed COVID-19 Cases')
plt.show()
```




```
plt.figure(figsize=(10,8))
sns.scatterplot(x='Confirmed', y='Deaths', data=df, hue='WHO Region', alpha=0.8, s=100, palette='viridis', marker='o')
plt.xscale('log')
plt.yscale('log')
plt.title('Relationship between Confirmed Cases and Deaths (Log Scale) by WHO Region')
plt.show()
```

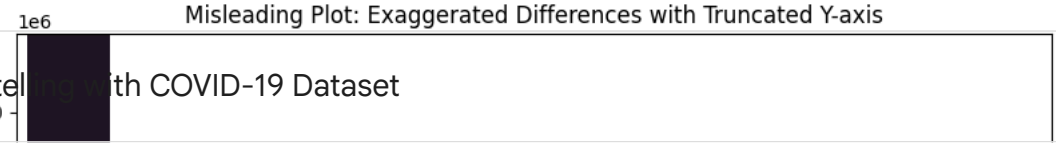



```
plt.figure(figsize=(10,8))
sns.heatmap(df[['Confirmed','Deaths','Recovered','Active']].corr(), annot=True, cmap='plasma', fmt=".2f", linewidths=.5)
plt.title('Correlation Matrix of Key COVID-19 Metrics')
plt.show()
```



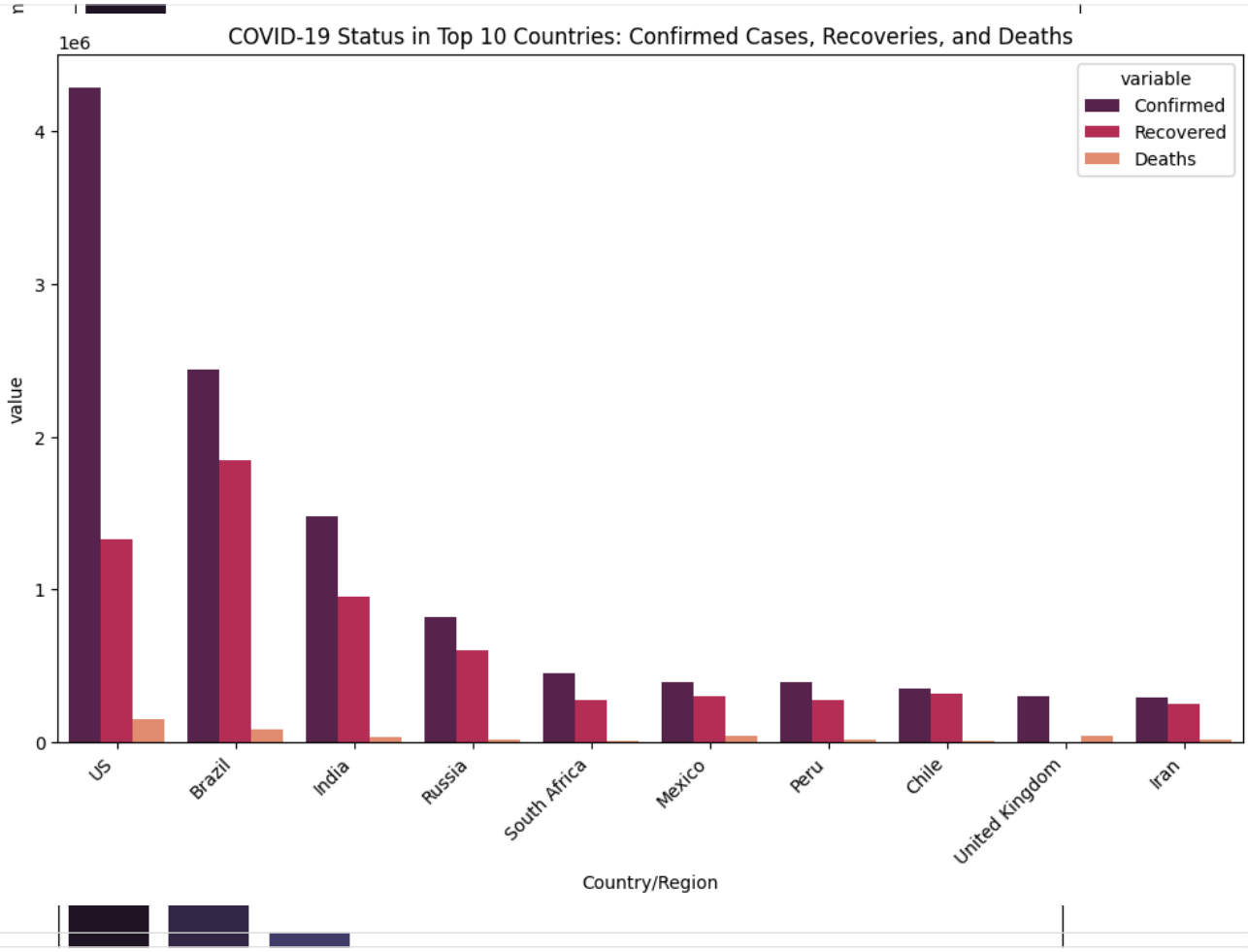
2. Misleading Visualization Example

```
top10 = df.nlargest(10, 'Confirmed')

plt.figure(figsize=(10,6))
sns.barplot(x='Country/Region', y='Confirmed', data=top10, palette='mako', hue='Country/Region', legend=False)
plt.ylim(2000000, top10['Confirmed'].max())
plt.title('Misleading Plot: Exaggerated Differences with Truncated Y-axis')
plt.xticks(rotation=45, ha='right')
plt.show()

plt.figure(figsize=(10,6))
sns.barplot(x='Country/Region', y='Confirmed', data=top10, palette='mako', hue='Country/Region', legend=False)
plt.title('Corrected Plot: Accurate Representation with Full Y-axis')
plt.xticks(rotation=45, ha='right')
plt.show()
```

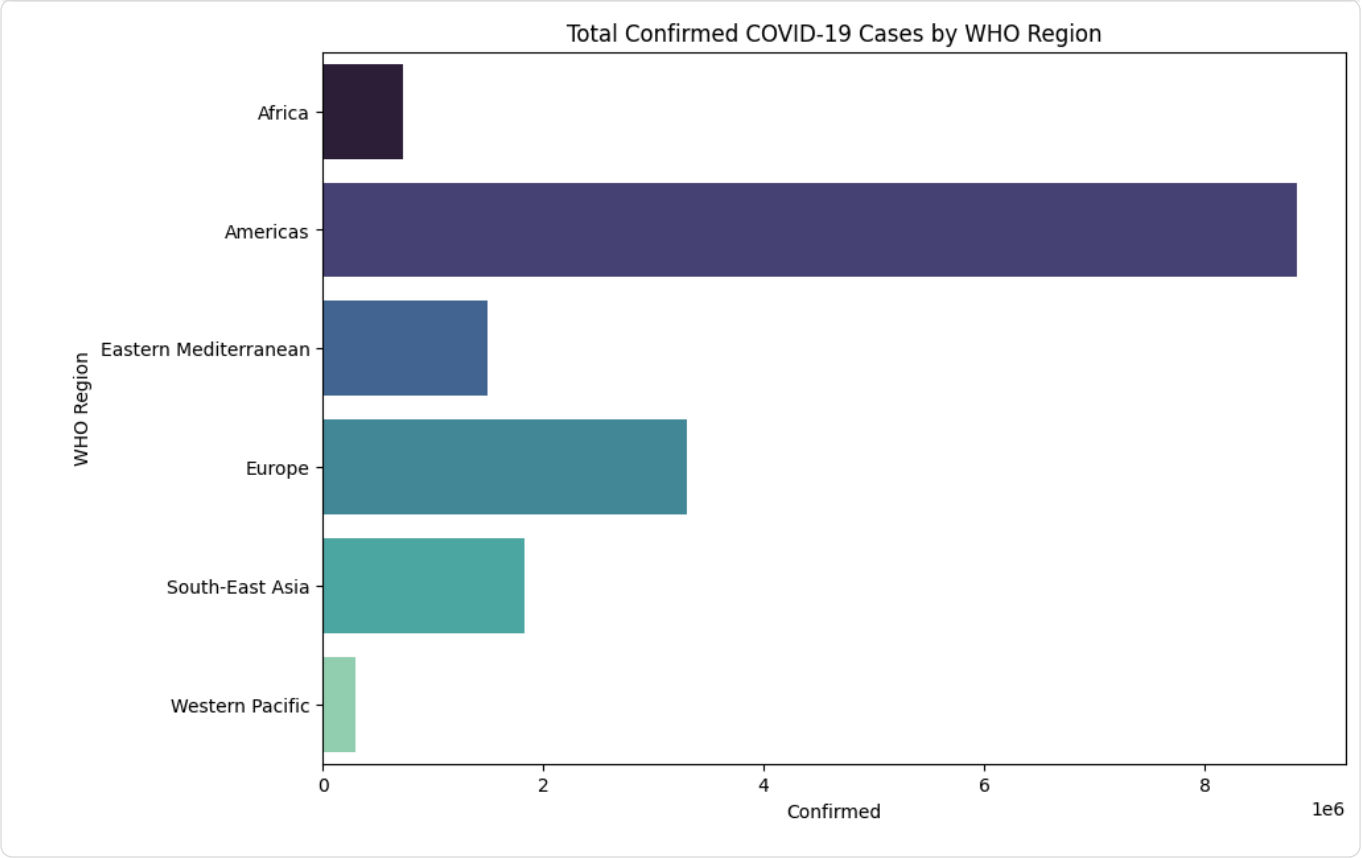


3. Storytelling with COVID-19 Dataset

```
plt.figure(figsize=(12,7))
top10_melt = top10.melt(id_vars=['Country/Region'], value_vars=['Confirmed','Recovered','Deaths'])
sns.barplot(x='Country/Region', y='value', hue='variable', data=top10_melt, palette='rocket', dodge=True)
plt.title('COVID-19 Status in Top 10 Countries: Confirmed Cases, Recoveries, and Deaths')
plt.xticks(rotation=45, ha='right')
plt.show()
```




```
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns

df = pd.read_csv('country_wise_latest.csv')

region_df = df.groupby('WHO Region')[['Confirmed','Deaths','Recovered']].sum().reset_index()
plt.figure(figsize=(10,7))
sns.barplot(x='Confirmed', y='WHO Region', data=region_df, palette='mako', hue='WHO Region', legend=False)
plt.title('Total Confirmed COVID-19 Cases by WHO Region')
plt.show()
```



What We Learned:

- Some countries have a lot more COVID-19 cases than others.
- Using a special kind of scale (log scale) helps us see big differences easily.
- Be careful! Charts can sometimes be misleading, like when they don't show the whole picture.
- Looking at different areas helps us understand where cases are happening the most.

Streamlit and Cloudflared

```
!pip install --quiet streamlit pandas numpy seaborn matplotlib plotly folium pycountry
```

```
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 10.1/10.1 MB 32.3 MB/s eta 0:00:00
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 6.3/6.3 MB 28.3 MB/s eta 0:00:00
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 6.9/6.9 MB 23.9 MB/s eta 0:00:00
```

```
import os
os.makedirs('.streamlit', exist_ok=True)
config = '[server]\nheadless = true\nport = 8501\nenableCORS = false\n'
with open('.streamlit/config.toml', 'w', encoding='utf-8') as config_file:
    config_file.write(config)
```

```
%%writefile app.py
import streamlit as st
import pandas as pd
import numpy as np
import seaborn as sns
import matplotlib.pyplot as plt
import plotly.express as px
import plotly.io as pio
from streamlit.components.v1 import html
import folium
from folium.plugins import MiniMap, Fullscreen, MousePosition, Search, MeasureControl
import requests
import pycountry
import math

DATA_PATH = "https://files.vxrachit.is-a.dev/datasets/country_wise_latest.csv"

CUSTOM_COLORS = [
    "#1f77b4",
```

```
    "#ff7f0e",
    "#2ca02c",
    "#d62728",
    "#9467bd",
    "#8c564b",
    "#e377c2",
    "#7f7f7f",
    "#bcbd22",
    "#17becf"
]

sns.set_palette(CUSTOM_COLORS)
plt.rcParams["axes.prop_cycle"] = plt.cycler(color=CUSTOM_COLORS)
pio.templates.default = "plotly_white"
px.defaults.color_discrete_sequence = CUSTOM_COLORS

@st.cache_data
def load_data():
    return pd.read_csv(DATA_PATH)

def prepare_data(df):
    df = df.copy()
    df.columns = [col.strip() for col in df.columns]
    if "Country/Region" in df.columns:
        df = df.rename(columns={"Country/Region": "Country"})
    if "Country" not in df.columns:
        df["Country"] = df.index.astype(str)
    if "WHO Region" not in df.columns:
        df["WHO Region"] = "Unknown"
    for col in df.select_dtypes(include=["object"]).columns:
        if any(token in col.lower() for token in ["date", "time", "day"]):
            converted = pd.to_datetime(df[col], errors="coerce")
            if converted.notna().sum() > 0:
                df[col] = converted
    if "Recovered / 100 Cases" in df.columns:
        df["Vaccination Status"] = pd.cut(
            df["Recovered / 100 Cases"],
            bins=[-np.inf, 40, 70, np.inf],
            labels=["Low", "Moderate", "High"]
        ).astype(str)
    else:
        df["Vaccination Status"] = "Not Reported"
    if "Confirmed" in df.columns and "Deaths" in df.columns:
        df["Case Fatality Rate"] = np.where(
            df["Confirmed"] > 0,
            df["Deaths"] / df["Confirmed"] * 100,
            0
        )
    numeric_columns = df.select_dtypes(include=[np.number]).columns
    df[numeric_columns] = df[numeric_columns].apply(pd.to_numeric, errors="coerce")
    return df

def get_datetime_columns(df):
    return [col for col in df.columns if pd.api.types.is_datetime64_any_dtype(df[col])]

def get_numeric_columns(df):
    return df.select_dtypes(include=[np.number]).columns.tolist()

def map_country_to_iso3(name):
    overrides = {
        "Bolivia": "BOL",
        "Brunei": "BRN",
        "Cabo Verde": "CPV",
        "Congo (Brazzaville)": "COG",
        "Congo (Kinshasa)": "COD",
        "Cote d'Ivoire": "CIV",
        "Czechia": "CZE",
        "Eswatini": "SWZ",
        "Holy See": "VAT",
        "Korea, South": "KOR",
        "Kosovo": "XKX",
        "Laos": "LAO",
        "Moldova": "MDA",
        "Russia": "RUS",
        "Syria": "SYR",
        "Taiwan*": "TWN",
        "Tanzania": "TZA",
        "US": "USA",
        "Vietnam": "VNM"
    }
    if name in overrides:
        return overrides[name]
```

```
    try:
        return pycountry.countries.lookup(name).alpha_3
    except LookupError:
        return None
    except KeyError:
        return None

def add_iso_codes(df):
    iso_df = df.copy()
    iso_df["ISO3"] = iso_df["Country"].apply(map_country_to_iso3)
    return iso_df.dropna(subset=["ISO3"])

def filter_dataframe(df, countries, regions, statuses, confirmed_range, deaths_range, recovered_range, active_range, new_cas
    filtered = df.copy()
    if countries:
        filtered = filtered[filtered["Country"].isin(countries)]
    if regions:
        filtered = filtered[filtered["WHO Region"].isin(regions)]
    if statuses:
        filtered = filtered[filtered["Vaccination Status"].astype(str).isin(statuses)]
    if "Confirmed" in filtered.columns:
        filtered = filtered[(filtered["Confirmed"] >= confirmed_range[0]) & (filtered["Confirmed"] <= confirmed_range[1])]
    if "Deaths" in filtered.columns:
        filtered = filtered[(filtered["Deaths"] >= deaths_range[0]) & (filtered["Deaths"] <= deaths_range[1])]
    if "Recovered" in filtered.columns:
        filtered = filtered[(filtered["Recovered"] >= recovered_range[0]) & (filtered["Recovered"] <= recovered_range[1])]
    if "Active" in filtered.columns:
        filtered = filtered[(filtered["Active"] >= active_range[0]) & (filtered["Active"] <= active_range[1])]
    if "New cases" in filtered.columns:
        filtered = filtered[(filtered["New cases"] >= new_cases_range[0]) & (filtered["New cases"] <= new_cases_range[1])]
    if date_column and date_column in filtered.columns and date_range:
        filtered = filtered[(filtered[date_column] >= date_range[0]) & (filtered[date_column] <= date_range[1])]
    if search_query:
        text = search_query.lower()
        filtered = filtered[filtered.apply(lambda row: row.astype(str).str.lower().str.contains(text).any(), axis=1)]
    if sort_column and sort_column in filtered.columns:
        filtered = filtered.sort_values(sort_column, ascending=ascending)
    return filtered

def render_metrics(df):
    metric_columns = st.columns(4)
    if "Confirmed" in df.columns:
        metric_columns[0].metric("Confirmed", f"{df['Confirmed'].sum():,.0f}")
    if "Deaths" in df.columns:
        metric_columns[1].metric("Deaths", f"{df['Deaths'].sum():,.0f}")
    if "Recovered" in df.columns:
        metric_columns[2].metric("Recovered", f"{df['Recovered'].sum():,.0f}")
    if "Case Fatality Rate" in df.columns:
        metric_columns[3].metric("Case Fatality Rate", f"{df['Case Fatality Rate'].mean():.2f}%")

def render_seaborn_plots(df):
    if {"WHO Region", "Confirmed"}.issubset(df.columns):
        region_summary = df.groupby("WHO Region", as_index=False)["Confirmed"].sum().sort_values("Confirmed", ascending=Fals
        fig, ax = plt.subplots(figsize=(10, 6))
        sns.barplot(data=region_summary, x="Confirmed", y="WHO Region", ax=ax)
        st.pyplot(fig)
        plt.close(fig)
    numeric_df = df.select_dtypes(include=[np.number])
    if numeric_df.shape[1] >= 2:
        corr = numeric_df.corr()
        fig, ax = plt.subplots(figsize=(10, 6))
        sns.heatmap(corr, cmap="magma", annot=True, fmt=".2f", ax=ax)
        st.pyplot(fig)
        plt.close(fig)
    if {"WHO Region", "Case Fatality Rate"}.issubset(df.columns):
        subset = df.dropna(subset=["Case Fatality Rate", "WHO Region"])
        if not subset.empty:
            fig, ax = plt.subplots(figsize=(10, 6))
            sns.boxplot(data=subset, x="Case Fatality Rate", y="WHO Region", ax=ax)
            st.pyplot(fig)
            plt.close(fig)
    if "Vaccination Status" in df.columns:
        status_counts = df["Vaccination Status"].value_counts().reset_index()
        status_counts.columns = ["Vaccination Status", "Count"]
        fig, ax = plt.subplots(figsize=(8, 5))
        sns.barplot(data=status_counts, x="Vaccination Status", y="Count", ax=ax)
        st.pyplot(fig)
        plt.close(fig)

def render_matplotlib_plots(df):
    required = {"Country", "Active", "Recovered", "Deaths", "Confirmed"}
    if required.issubset(df.columns):
```

```
        top_countries = df.nlargest(10, "Confirmed")["Country"].to_list()
        selection = df[df["Country"].isin(top_countries)][["Country", "Active", "Recovered", "Deaths", "Confirmed"]].drop_du
        if not selection.empty:
            positions = np.arange(len(selection))
            width = 0.25
            fig, ax = plt.subplots(figsize=(12, 6))
            ax.bar(positions - width, selection["Active"], width=width, label="Active")
            ax.bar(positions, selection["Recovered"], width=width, label="Recovered")
            ax.bar(positions + width, selection["Deaths"], width=width, label="Deaths")
            ax.set_xticks(positions)
            ax.set_xticklabels(selection.index, rotation=45, ha="right")
            ax.set_ylabel("People")
            ax.set_title("Active, Recovered, and Deaths for Top Confirmed Countries")
            ax.legend()
            st.pyplot(fig)
            plt.close(fig)
    if {"Country", "1 week change"}.issubset(df.columns):
        change = df.dropna(subset=["1 week change"]).nlargest(10, "1 week change")
        if not change.empty:
            fig, ax = plt.subplots(figsize=(10, 6))
            ax.barh(change["Country"], change["1 week change"])
            ax.set_xlabel("New Cases Compared to Last Week")
            ax.set_title("Largest Weekly Case Growth")
            st.pyplot(fig)
            plt.close(fig)

def render_plotly_charts(df):
    if {"Confirmed last week", "Confirmed", "Country"}.issubset(df.columns):
        line_df = df.sort_values("Confirmed last week")
        fig = px.line(line_df, x="Confirmed last week", y="Confirmed", color="Country", markers=True, title="Confirmed vs Co
        st.plotly_chart(fig, config={"responsive": True})
    if {"Confirmed", "Deaths", "Recovered", "Country", "WHO Region"}.issubset(df.columns):
        fig = px.scatter(df, x="Confirmed", y="Deaths", size="Recovered", color="WHO Region", hover_name="Country", title="D
        st.plotly_chart(fig, config={"responsive": True})
    if {"WHO Region", "Confirmed", "Deaths", "Recovered"}.issubset(df.columns):
        region_totals = df.groupby("WHO Region", as_index=False)[["Confirmed", "Deaths", "Recovered"]].sum()
        fig = px.treemap(region_totals, path=["WHO Region"], values="Confirmed", color="Deaths", color_continuous_scale="Red
        fig.update_traces(textinfo="label+value")
        st.plotly_chart(fig, config={"responsive": True})
    if {"Country", "New cases"}.issubset(df.columns):
        top_new = df.dropna(subset=["New cases"]).nlargest(10, "New cases")
        if not top_new.empty:
            fig = px.bar(top_new.sort_values("New cases", ascending=False), x="Country", y="New cases", color="New cases", t
            fig.update_layout(xaxis_tickangle=-45)
            st.plotly_chart(fig, config={"responsive": True})
    if {"Confirmed", "Active", "Recovered", "Deaths"}.issubset(df.columns):
        totals = df[["Confirmed", "Active", "Recovered", "Deaths"]].sum().rename_axis("Status").reset_index(name="Count")
        fig = px.funnel(totals, y="Status", x="Count", color="Status", title="Global Outcome Funnel")
        st.plotly_chart(fig, config={"responsive": True})

def render_folium_map(df):
    if "Country" not in df.columns or "Confirmed" not in df.columns:
        st.write("Map unavailable for this dataset.")
        return
    map_df = add_iso_codes(df.groupby("Country", as_index=False)["Confirmed"].sum())
    if map_df.empty:
        st.write("Map unavailable for this dataset.")
        return
    try:
        geojson_url = "https://raw.githubusercontent.com/python-visualization/folium/master/examples/data/world-countries.js
        geojson_data = requests.get(geojson_url, timeout=10).json()
        value_map = map_df.set_index("ISO3")["Confirmed"].to_dict()
        for feature in geojson_data.get("features", []):
            iso = feature.get("id")
            feature.setdefault("properties", {})
            feature["properties"]["Confirmed"] = int(value_map.get(iso, 0))
            feature["properties"]["ISO3"] = iso
        folium_map = folium.Map(location=[20, 0], zoom_start=2, tiles=None)
        folium.TileLayer("cartodbpositron", name="Light").add_to(folium_map)
        folium.TileLayer("cartodbdark_matter", name="Dark").add_to(folium_map)
        folium.TileLayer("OpenStreetMap", name="OSM").add_to(folium_map)
        choropleth = folium.Choropleth(
            geo_data=geojson_data,
            data=map_df,
            columns=["ISO3", "Confirmed"],
            key_on="feature.id",
            fill_color="YlOrRd",
            nan_fill_color="lightgray",
            legend_name="Confirmed Cases",
            name="Choropleth"
        )
        choropleth.add_to(folium_map)
```

```
            tooltip = folium.features.GeoJsonTooltip(
                fields=["name", "ISO3", "Confirmed"],
                aliases=["Country", "ISO3", "Confirmed"],
                localize=True,
                sticky=True
            )
            popup = folium.features.GeoJsonPopup(
                fields=["name", "ISO3", "Confirmed"],
                aliases=["Country", "ISO3", "Confirmed"],
                localize=True
            )
            gjson = folium.GeoJson(
                geojson_data,
                name="Country boundaries",
                style_function=lambda f: {"fillColor": "transparent", "color": "#555", "weight": 0.5, "fillOpacity": 0},
                highlight_function=lambda f: {"weight": 2, "color": "#000", "fillOpacity": 0.1},
                tooltip=tooltip,
                popup=popup
            )
            gjson.add_to(folium_map)
            Search(layer=gjson, search_label="name", geom_type="Polygon", collapsed=False).add_to(folium_map)
            MiniMap(toggle_display=True).add_to(folium_map)
            Fullscreen().add_to(folium_map)
            MousePosition().add_to(folium_map)
            MeasureControl(primary_length_unit="kilometers").add_to(folium_map)
            folium.LayerControl(collapsed=False).add_to(folium_map)
            html(folium_map._repr_html_(), height=520)
        except Exception as error:
            st.write("Map data unavailable.")
            st.write(str(error))

    def render_data_table(df, page_size, page_number):
        start_index = (page_number - 1) * page_size
        end_index = start_index + page_size
        st.dataframe(df.iloc[start_index:end_index], width='stretch')

    def numeric_slider(df, label, column):
        if column in df.columns:
            series = df[column].dropna()
            if series.empty:
                st.sidebar.write(f"{label} unavailable")
                return (0, 0)
            min_val = int(series.min())
            max_val = int(series.max())
            if min_val == max_val:
                st.sidebar.write(f"{label}: {min_val}")
                return (min_val, max_val)
            return st.sidebar.slider(label, min_val, max_val, (min_val, max_val))
        st.sidebar.write(f"{label} unavailable")
        return (0, 0)

    def render_insight_panels(df):
        if {"Country", "Case Fatality Rate"}.issubset(df.columns):
            top_cfr = df.dropna(subset=["Case Fatality Rate"]).nlargest(10, "Case Fatality Rate")
            if not top_cfr.empty:
                fig = px.bar(top_cfr.sort_values("Case Fatality Rate"), x="Case Fatality Rate", y="Country", orientation="h", ti
                st.plotly_chart(fig, config={"responsive": True})
        if {"Country", "Recovered / 100 Cases"}.issubset(df.columns):
            top_recovery = df.dropna(subset=["Recovered / 100 Cases"]).nlargest(10, "Recovered / 100 Cases")
            if not top_recovery.empty:
                fig = px.bar(top_recovery.sort_values("Recovered / 100 Cases"), x="Recovered / 100 Cases", y="Country", orientat
                st.plotly_chart(fig, config={"responsive": True})
        if {"Country", "1 week % increase"}.issubset(df.columns):
            fastest_growth = df.dropna(subset=["1 week % increase"]).nlargest(10, "1 week % increase")
            if not fastest_growth.empty:
                fig = px.line(fastest_growth.sort_values("1 week % increase", ascending=False), x="Country", y="1 week % increas
                st.plotly_chart(fig, config={"responsive": True})

    def main():
        st.set_page_config(page_title="Global COVID-19 Dashboard", layout="wide")
        st.markdown(
            """
            <div style="text-align: center; padding: 1rem 0;">
                <h1>Global COVID-19 Dashboard</h1>
                <p style="font-size: 1.1rem;">Interactive analytics powered by Streamlit, Seaborn, Plotly, and Folium</p>
            </div>
            """,
            unsafe_allow_html=True
        )
        df = load_data()
        df = prepare_data(df)
        datetime_columns = get_datetime_columns(df)
```

```
st.sidebar.header("Filter Controls")
with st.sidebar.expander("Geography Filters", expanded=True):
    countries = sorted(df["Country"].dropna().unique().tolist()) if "Country" in df.columns else []
    selected_countries = st.multiselect("Countries", countries)
    regions = sorted(df["WHO Region"].dropna().unique().tolist()) if "WHO Region" in df.columns else []
    selected_regions = st.multiselect("WHO Regions", regions)
with st.sidebar.expander("Status Filters", expanded=False):
    statuses = sorted(df["Vaccination Status"].dropna().unique().tolist()) if "Vaccination Status" in df.columns else []
    selected_statuses = st.multiselect("Vaccination Status", statuses)
with st.sidebar.expander("Numeric Ranges", expanded=False):
    confirmed_range = (0, 0)
    deaths_range = (0, 0)
    recovered_range = (0, 0)
    active_range = (0, 0)
    new_cases_range = (0, 0)

    if "Confirmed" in df.columns:
        confirmed_range = numeric_slider(df, "Confirmed cases range", "Confirmed")
    if "Deaths" in df.columns:
        deaths_range = numeric_slider(df, "Deaths range", "Deaths")
    if "Recovered" in df.columns:
        recovered_range = numeric_slider(df, "Recovered range", "Recovered")
    if "Active" in df.columns:
        active_range = numeric_slider(df, "Active range", "Active")
    if "New cases" in df.columns:
        new_cases_range = numeric_slider(df, "New cases range", "New cases")

with st.sidebar.expander("Date & Sorting", expanded=False):
    date_column, date_range = None, None
    if datetime_columns:
        options = ["None"] + datetime_columns
        selected_option = st.selectbox("Date column", options)
        if selected_option != "None":
            date_column = selected_option
            min_date = df[date_column].min()
            max_date = df[date_column].max()
            if min_date == max_date:
                date_range = (min_date, max_date)
                st.write(f"Date range fixed at {min_date}")
            else:
                date_range = st.slider("Date range", min_value=min_date, max_value=max_date, value=(min_date, max_date))
    search_query = st.text_input("Search text")
    sort_column_option = st.selectbox("Sort column", ["None"] + df.columns.tolist())
    sort_column = None if sort_column_option == "None" else sort_column_option
    sort_order = st.radio("Sort order", ["Ascending", "Descending"], index=0)
    ascending = sort_order == "Ascending"
page_size = st.sidebar.slider("Rows per page", 10, 100, 25, 5)
filtered_df = filter_dataframe(
    df, selected_countries, selected_regions, selected_statuses,
    confirmed_range, deaths_range, recovered_range,
    active_range, new_cases_range,
    search_query, date_column, date_range,
    sort_column, ascending
)
total_pages = max(1, math.ceil(len(filtered_df) / page_size))
page_number = st.sidebar.number_input("Page number", min_value=1, max_value=total_pages, value=1, step=1)
st.sidebar.write(f"Total rows: {len(filtered_df)}")
csv_data = filtered_df.to_csv(index=False).encode("utf-8")
st.sidebar.download_button("Download filtered data", csv_data, "filtered_covid_data.csv", "text/csv")
overview_tab, seaborn_tab, plotly_tab, map_tab, insights_tab = st.tabs(
    ["Overview", "Matplotlib & Seaborn", "Plotly", "Folium Map", "Insights"]
)
with overview_tab:
    st.subheader("Key Global Metrics")
    render_metrics(filtered_df)
    st.markdown("---")
    col1, col2 = st.columns([2, 1])
    with col1:
        st.subheader("Filtered Data")
        render_data_table(filtered_df, page_size, page_number)
    with col2:
        if {"Country", "Confirmed", "Deaths", "Recovered", "Active"}.issubset(filtered_df.columns):
            top_overview = filtered_df.nlargest(5, "Confirmed")["Country"].to_list()
            selection = filtered_df[filtered_df["Country"].isin(top_overview)][
                ["Country", "Confirmed", "Deaths", "Recovered", "Active"]
            ].drop_duplicates("Country").set_index("Country")
            if not selection.empty:
                st.subheader("Top 5 by Confirmed")
                st.dataframe(selection, width='stretch')
with seaborn_tab:
    st.subheader("Regional Trends & Distributions")
    render_seaborn_plots(filtered_df)
```

```
        st.markdown("---")
        st.subheader("Matplotlib Comparisons")
        render_matplotlib_plots(filtered_df)
    with plotly_tab:
        st.subheader("Interactive Plotly Visuals")
        render_plotly_charts(filtered_df)
    with map_tab:
        st.subheader("Geospatial Spread")
        render_folium_map(filtered_df)
    with insights_tab:
        st.subheader("Insight Highlights")
        render_insight_panels(filtered_df)
```

```
Writing app.py
```

```
!wget -q https://github.com/cloudflare/cloudflared/releases/latest/download/cloudflared-linux-amd64 -O cloudflared
!chmod +x cloudflared
```

```
!pip install -q streamlit

import threading
import subprocess
import time
import re

port = 8501

def run_streamlit():
    print(f"Running Streamlit on port {port}...")
    subprocess.Popen(
        ["streamlit", "run", "app.py", "--server.port", str(port), "--server.headless", "true"],
        stdout=subprocess.DEVNULL,
        stderr=subprocess.STDOUT,
        text=True
    )

def run_cloudflared():
    print("Starting Cloudflare Tunnel...")
    process = subprocess.Popen(
        ["./cloudflared", "tunnel", "--url", f"http://localhost:{port}", "--no-autoupdate"],
        stdout=subprocess.PIPE,
        stderr=subprocess.STDOUT,
        text=True,
        bufsize=1
```