ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

Fakulta stavební

Kartografické zpracování vybraných aspektů epidemie nemoci Covid-19

Cartographic processing of selected aspects of the Covid-19 pandemy

BAKALÁŘSKÁ PRÁCE

Shvets Kateryna

Studijní obor: Geodézie a kartografie

Vedoucí bakalářské práce: Tomáš Janata

Praha, 2024

ZADÁNÍ BAKALÁŘSKÉ PRÁCE

I. OSOBNÍ A STUDIJNÍ ÚDAJE

Příjmení: **Shvets**   Jméno: **Kateryna**   Osobní číslo: **493675**

Fakulta/ústav: **Fakulta stavební**

Zadávající katedra/ústav: **Katedra geomatiky**

Studijní program: **Geodézie a kartografie**

II. ÚDAJE K BAKALÁŘSKÉ PRÁCI

Název bakalářské práce:

Kartografické zpracování vybraných aspektů epidemie nemoci Covid-19

Název bakalářské práce anglicky:

Cartographic processing of selected aspects of the Covid-19 pandemy

Pokyny pro vypracování:

Rešerše stavu řešení problematiky, kartografické výstupy se zdravotnickou tematikou.
Shromáždění dat k prostorovému vývoji pandemie i k tematické složce – vybrané aspekty, kartograficky méně často užívanými metodami. Časová složka, zobrazení geneze pandemie pomocí časových map.
Tvorba digitální mapové aplikace zobrazující zajímavé skutečnosti vývoje pandemie.

Seznam doporučené literatury:

Voženílek, V., Kaňok, J., a kol.: Metody tematické kartografie – Vizualizace prostorových jevů. Univerzita Palackého v Olomouci, 2011.
Bláha, J. D.: Vybrané okruhy z geografické kartografie. Ústí nad Labem: Univerzita J. E. Purkyně, 2017.

Jméno a pracoviště vedoucí(ho) bakalářské práce:

Ing. Tomáš Janata, Ph.D.   Katedra geomatiky   FSv

Jméno a pracoviště druhé(ho) vedoucí(ho) nebo konzultanta(ky) bakalářské práce:

Datum zadání bakalářské práce: **26.02.2024**   Termín odevzdání bakalářské práce: **20.05.2024**

Platnost zadání bakalářské práce: _____

_____	_____	_____
Ing. Tomáš Janata, Ph.D.	prof. Dr. Ing. Karel Pavelka	prof. Ing. Jiří Máca, CSc.
podpis vedoucí(ho) práce	podpis vedoucí(ho) ústavu/katedry	podpis děkana(ky)

III. PŘEVZETÍ ZADÁNÍ

Studentka bere na vědomí, že je povinna vypracovat bakalářskou práci samostatně, bez cizí pomoci, s výjimkou poskytnutých konzultací.
Seznam použité literatury, jiných pramenů a jmen konzultantů je třeba uvést v bakalářské práci.

_____	_____
Datum převzetí zadání	Podpis studentky

Prohlášení

Prohlašuji, že jsem bakalářskou práci na téma "Kartografické zpracování vybraných aspektů epidemie nemoci Covid-19" zpracoval(a) samostatně za použití uvedené literatury a pramenů.

Dále prohlašuji, že nemám závažný důvod proti užití tohoto školního díla ve smyslu § 60 zákona č. 121/2000 Sb., o právu autorském, o právech souvisejících s právem autorským a o změně některých zákonů (autorský zákon).

V Praze dne 10.04.2024

………………………………

Shvets Kateryna

Poděkování

Děkuji Ing. Tomáši Janatovi, Ph.D za jeho odborné vedení a užitečné rady při zpracování bakalářské práce a také za vstřícnost a poskytnuté konzultace. Děkuji také svým přátelům za podporu v průběhu psaní práce.

Abstrakt

Bakalářská práce se věnuje vizualizaci vybraných aspektů COVID-19: celkový počet případů, celkový počet úmrtí, celkový počet případů na milion a celkový počet úmrtí na milion s vytvořením časových animací. Konečným produktem bude 9 animací zobrazujících vývoj aspektů COVID-19 v čase ve střední Evropě, Africe a jedna pro celkový počet úmrtí na milion celosvětově pro země s 10 nejvyššími hodnotami.

Klíčová slova:

COVID-19

Časové mapování

Prostorové mapování

Animace v časovém sledu

Abstract

The bachelor's thesis is dedicated to visualising chosen aspects of COVID-19: total cases, total deaths, total cases per million and total deaths per million with creating time-lapse animations. The final product will be 9 animations displaying developing COVID-19 aspects over time in central Europe, Africa and one for total deaths per million worldwide for countries with top-10 highest values.

Keywords:

COVID-19

Temporal Mapping

Spatial Mapping

Time-lapse animations

Summary

Introduction

This topic was chosen because of a few reasons. First is practical, I was interested in cartography and geomatics, and I see myself being involved in this in the future. Also, the opportunity to analyse, clean, arrange the big source of data and the ability to visualise it afterwards is a great skill to gain, which is possible during work on this project. My idea was to prove that ArcGIS functionality, especially temporal mapping methods are good enough for creating a project that can solve some planning or visualising problems.

The final product of this project will be 9 animations, visualising certain COVID-19 aspects in time in central Europe, Africa, and countries with top-amount of death cases.

Also, this work will show how big-scale events like COVID-19 with this large amount of data can be visualised with methods I used, so these methods can be or be not considered for further possible projects. My personal interest in this was to test a few temporal mapping methods to visualise some of COVID-19 aspects.

By pursuing these research objectives, this thesis aims to advance our understanding of the COVID-19 pandemic's global dynamics and contribute to the understanding of cartographic visualisation methods and their limits in health crises like COVID-19. From the professional side the aim is to test how close you can get with having ArcGIS and basic tools to create a project for visualising a big-scale data event.

1. History and development of COVID-19

The emergence of COVID-19, caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has brought about an unprecedented global health crisis.

The spread of COVID-19 across the world can be attributed to various factors, including globalisation, international travel, and the highly contagious nature of the virus. Bats are considered the natural reservoir of the virus, and it is possible that an animal host played a role in transmission to humans. Early cases of people getting sick have been connected to places called wet markets. These markets are where all kinds of animals are kept close together. Here is an overview of how COVID-19 spread globally:

- First outbreak in Wuhan, China:

The first cases of COVID-19 were reported in December 2019 in Wuhan, Hubei Province, China. The virus likely originated from an animal source, possibly in a seafood market. The initial spread was primarily localised within Wuhan and surrounding regions.

- International travel:

As Wuhan is a major transportation hub, the virus quickly spread beyond China's borders through international travel. People who were sick with the virus didn't know about it and travelled to other countries. This helped the virus spread to new places and start causing problems there too. During the first days of COVID-19 pandemic the very first cases were confirmed afterwards in France and Italy.

- Community transmission:

Once the virus reached other countries, it began spreading within local communities through close contact with infected people. The virus spread when people were close to each other, especially indoors, like in homes, offices, or when they got together

with friends. It happened when infected people breathed, coughed, or sneezed, sending tiny drops of liquid into the air.

- Global travel and tourism:

The interconnectedness of the modern world facilitated the rapid international spread of COVID-19. Air travel, in particular, played a significant role in carrying the virus across continents. Infected people could unknowingly transmit the virus during travel, leading to new outbreaks in previously unaffected regions.

- Asymptomatic and pre-symptomatic spread:

One challenging aspect of COVID-19 is that infected people can spread the virus even before experiencing symptoms or while having none. This feature allowed the virus to go undetected and contributed to its rapid transmission among people and all around the world.

- Local outbreaks:

Big gatherings like parties, religious ceremonies, or conferences became hotspots for spreading the virus quickly. They're called "superspreading events." When people didn't follow safety rules or ignored instructions, it made it really tough to control the virus and stop it from spreading further.

- Border controls and containment measures:

Countries implemented various measures to control the spread of the virus, such as travel restrictions, quarantine protocols, and social distancing measures. While these measures helped slow down the spread, community transmission and localised outbreaks still occurred.

- Global pandemic declaration:

In March 2020, the World Health Organization (WHO) declared COVID-19 a global pandemic due to its widespread and sustained transmission across multiple countries

and continents. This declaration highlighted the urgent need for coordinated international efforts to combat the virus.

- Vaccination efforts:

The development and distribution of COVID-19 vaccines have played a crucial role in curbing the spread of the virus. Vaccination drives have been happening all around the world. They were focusing on vaccinating people who are at high risk first. The goal is to get as many people vaccinated as possible to stop the virus from spreading more.

It's important to note that the specific trajectory of COVID-19 spread varied from country to country based on factors such as population density, healthcare capacity, public health response, and adherence to preventive measures. Monitoring and responding to the evolving situation have been vital in containing and mitigating the impact of the pandemic.[1][2][3][14]

2. Research

2.1. Real-time data visualisation dashboards

The COVID-19 pandemic, declared a global health emergency by the World Health Organization (WHO) in March 2020, created an urgent need for clear and accessible information. Cartography emerged as a powerful tool for visualising the spread and patterns of the disease. While many informative dashboards were created during this time, a common challenge emerged: ensuring data visualisations are relevant and informative.

Several studies have documented the prevalence of outdated dashboards. This proves the need to develop practices in creating and maintaining real-time data visualisations.

According to public health expert Lauren Gardner "it is especially challenging to collect good data at a fine spatial resolution, which is what most people want to know, and without having travel data in real time that captures these altered mobility

patterns, it is hard to assess what the geographic risk profile will look like moving forward". [4][5]

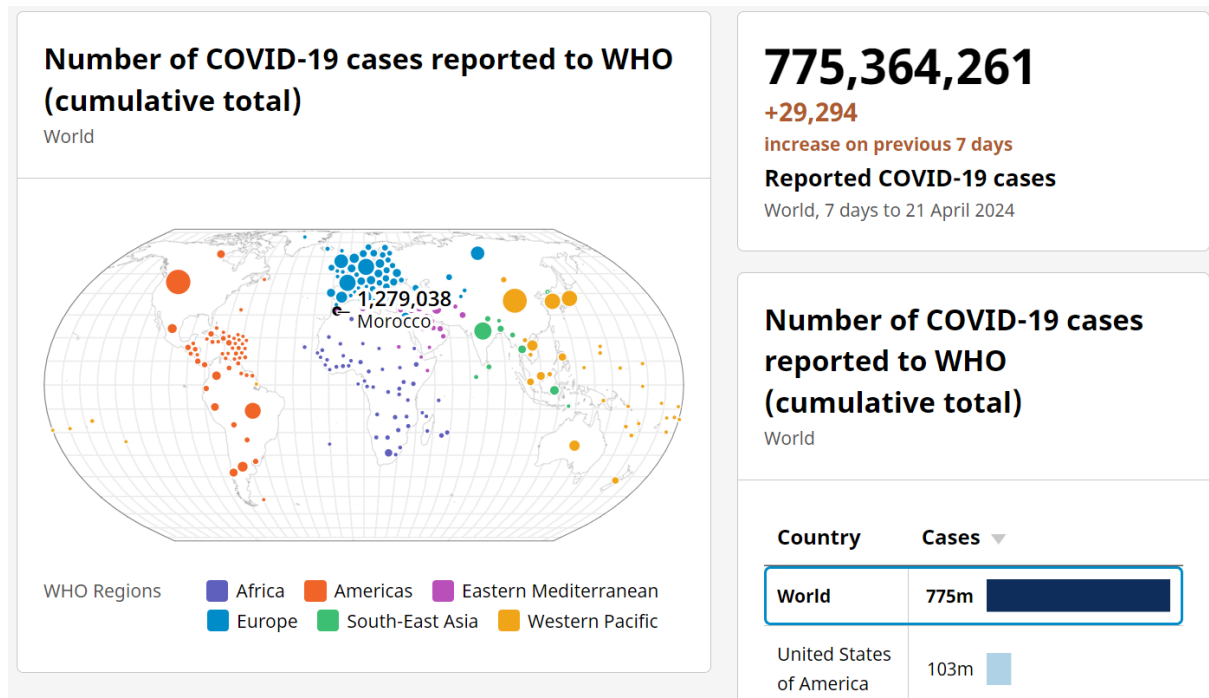2.1.1. World Health Organization (WHO) Coronavirus (COVID-19) Dashboard:

Image 1: WHO Coronavirus COVID-19 Dashboard
https://data.who.int/dashboards/covid19/cases

The World Health Organization (WHO) has a long history of leading the fight against global pandemics, including polio, Ebola, and most recently, COVID-19. During the COVID-19 pandemic, the WHO played a critical role in connecting with its members, providing preparedness and response guidance, and offering valuable geospatial technology.

The centrepiece is a choropleth map depicting the global distribution of cases, with interactive features for exploring country-specific data. Additionally, line graphs and bar charts effectively visualise trends over time.

The WHO dashboard prioritises user-friendliness. It's accessible on mobile devices, allowing users to easily access accurate information on the go. The data updates

daily using ArcGIS GeoServer, ensuring users have access to the latest statistics.[4][6]

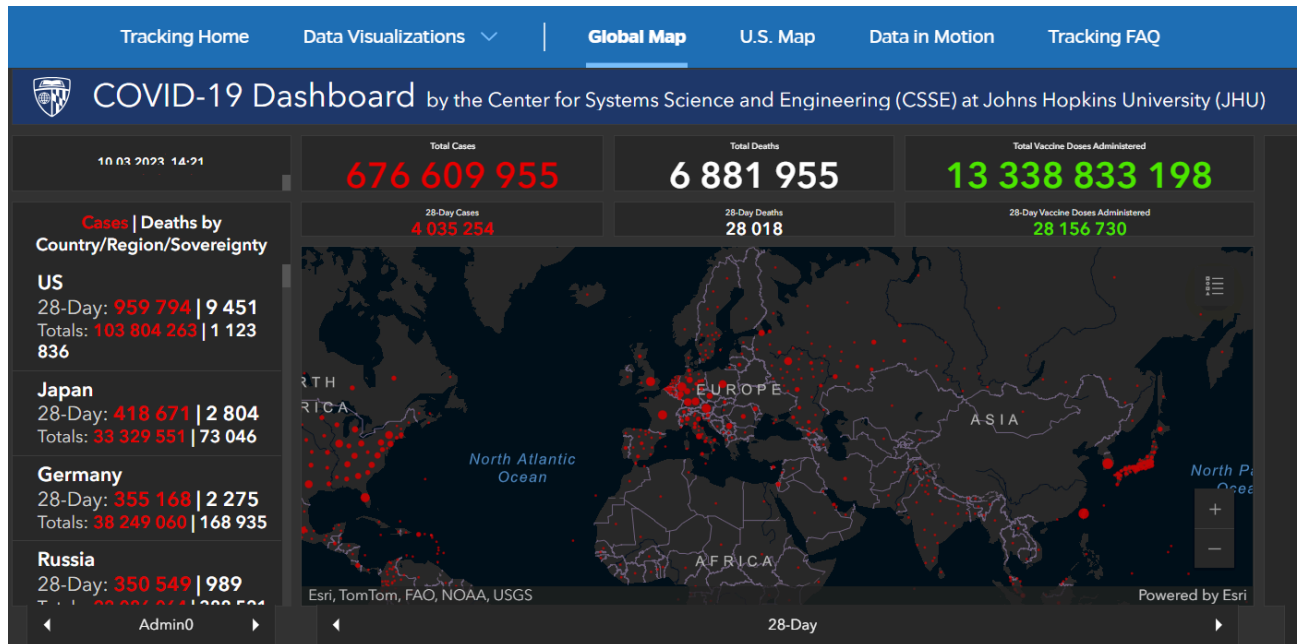### 2.1.2. Johns Hopkins University Covid-19 Dashboard

Image 2: Johns Hopkins University Covid-19 Dashboard
https://coronavirus.jhu.edu/map.html

Developed by Johns Hopkins University's Center for Systems Science and Engineering (CSSE), this resource offers a global map visualising confirmed COVID-19 cases. It employs proportional symbology, where circle markers on the map increase in size based on the number of cases in each location. This method allows viewers to easily identify areas with higher caseloads. [7]

2.1.3. ESRI - Mapping the spread of COVID-19 in story maps

Providing accessible, global COVID-19 updates

The Mapping the novel coronavirus pandemic story map offers a snapshot of current COVID-19 cases, background information, and links to additional resources.

The story presents the complex and changing COVID-19 data in three simple visuals—a map, dashboard, and chart updated daily—with concise descriptions that make the make complex information more accessible to the average reader.

View the story

Image 3: ArcGIS StoryMaps

https://storymaps.arcgis.com/stories/4fcddb805b0243988a42868f398a2ea0

This project by Esri has a narrative format to present the story of COVID-19 alongside thematic maps. Each logical step in the outbreak's progression is accompanied by a relevant map, such as the one illustrating the most popular flight routes from Wuhan, China, the initial epicentre. This approach provides valuable context and supports a deeper understanding of the pandemic's geographical dynamics. [8]

2.1.4. The Center for Coronavirus Information -ncov2019. live Dashboard

Image 4: -ncov2019.live Dashboard

https://ncov2019.live/

A high school student in Washington State, USA, created the ncov2019 dashboard. It originally only tracked data for the United States but was later expanded to include the entire world. The data comes from local government websites, hospitals, and health departments.

The ncov2019 dashboard offers a global view of COVID-19. It shows total confirmed cases, deaths, and recovered cases, along with population data for each country. This allows you to see the number of cases per million people. Additionally, the dashboard breaks down cases by continent (Asia, Europe, etc.) and provides details for individual countries. This includes information like active cases, daily changes in cases, critical patients, deaths per million, recovered cases, and the total number of tests done. [4][9]

2.2. Types of maps used the most for mapping COVID-19

Choropleth Maps: Among the most used during the pandemic, choropleth maps present divided geographical areas coloured or patterned in relation to a data variable. This technique is especially effective in illustrating variable quantities, like COVID-19 infection rates across countries or states. Each region's colour intensity reflects the magnitude of the variable.

Heat Maps: Heat maps convey the intensity of COVID-19 cases through colour variations. Particularly useful for illustrating the concentration of cases in densely populated areas, these maps excel in spotlighting COVID-19 hotspots. For instance, the New York Times frequently used heat maps to depict the intensity of infection rates across the United States. Nevertheless, heat maps may sometimes be misinterpreted as representing geographic area rather than density or quantity of cases.

Dot Distribution Maps: These maps employ dots to show the presence of COVID-19, where each dot represents a specific number of occurrences, such as cases, hospitalizations, or deaths. One powerful implementation was the map developed by University of Wisconsin-Madison, which used dots to display the density of COVID-19 cases in Wisconsin counties. These maps are, however, less effective in areas with high case numbers, where dots can overlap and obscure each other

Cartograms: Cartograms distort the geometry or space of the map to convey information, often showing a variable such as population size in relation to COVID-19 case numbers. For instance, Worldmapper published a series of cartograms demonstrating the global distribution of confirmed COVID-19 cases, adjusted for population size. Although providing valuable perspectives, cartograms can be challenging to understand and hard to process visually when it comes to big amounts of data.

2.3 Temporal maps for depicting big-scale events

Temporal maps are a powerful tool for researchers and communicators alike, allowing them to visualise the evolution of large-scale events over time and space. Here are some of the most common types of temporal maps used for depicting big-scale events:

- **Choropleth maps with time series:** These maps use colour or shading to represent data for different geographical regions across multiple time periods. This allows for a quick visual comparison of how a value, such as COVID-19 cases, has changed over time in different locations.

- **Isopleth maps:** These maps utilise lines to connect points with the same value at a specific time. Often used to illustrate travel times or the spread of a disease, isopleth maps are effective at showing how an event develops over time.
- **Space-time cubes:** space-time cubes offer a way to visualise spatiotemporal data through a cube where the base represents a geographic area (x and y axes), and the height represents time (z-axis). The cube is then divided into smaller cells (bins) representing specific locations and timeframes.
- **Dot distribution maps:** these maps represent data points with dots or symbols on a map. The size, colour, or density of the dots can be used to visualise additional information about the data point. [20][21][22]

2.4. Mapping methodology problems

While web-based maps are powerful tools for analysing infectious disease spread and disseminating public health information, their effectiveness relies mostly on user-friendly design. The complexity of disease data can be easily misinterpreted or overwhelm viewers if not presented clearly. Even well-intentioned maps can suffer from "data rich, information poor" (DRIP) syndrome, bombarding users with excessive details. This can be especially problematic when maps depicting different aspects of the pandemic, such as infection rates, testing sites, and population dynamics, use inconsistent spatial units or scales.

- **Inconsistent data:** maps may use different scales, units (e.g., cases vs. infection rates), or spatial aggregations (e.g., national vs. regional data) for the same information, making comparisons misleading.
- **Misuse of choropleth maps:** these maps, which colour code regions based on absolute values, can be misleading without proper normalisation for population size.
- **Data overload:** cramming too much information onto a single map can overwhelm viewers and hinder comprehension. This is especially relevant for non-expert audiences encountering complex disease data.

- **Global vs. local focus:** maps optimised for global audiences may not be informative for local areas, and vice versa.[10]
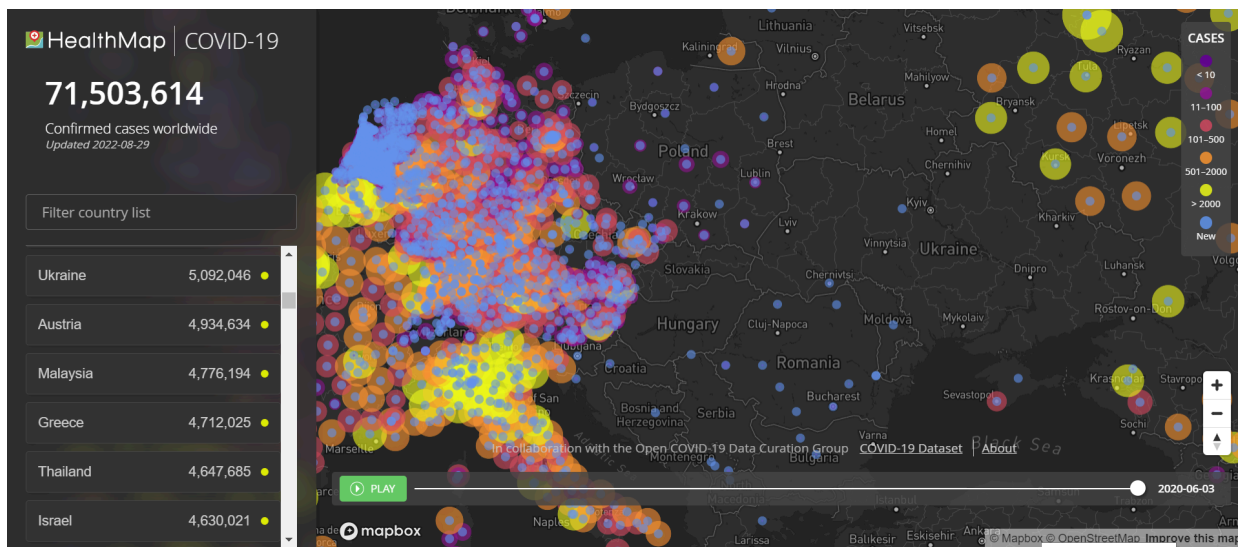

Image 5: Ukraine and Austria have the similar number of confirmed cases
https://www.healthmap.org/covid-19/

3. Description and preparing the data

3.1. Source of data

For this work it was needed to find a reliable and full source of data. The task was to find full, often updated worldwide data in numbers.

The dataset used in this thesis is sourced from Our World in Data, a reputable and widely recognized organisation focused on global development data. Specifically, the dataset is obtained from their GitHub repository (https://github.com/owid/covid-19-data/tree/master/public/data).

Our World in Data actively collects, verifies, and updates COVID-19 data from multiple sources, ensuring reliability and accuracy in their dataset. [12]

3.2. Data coverage and availability

 The dataset used in this thesis provides a comprehensive coverage of countries and regions worldwide, offering a global perspective on the COVID-19 pandemic. It

includes data from various continents, countries of different sizes, populations, and levels of development. This broad coverage allows for a comprehensive analysis of the pandemic's global impact and facilitates cross-country comparisons.

 It was possible to see that data availability and completeness vary across countries. Some countries had developed data reporting systems, providing detailed and timely information on COVID-19 cases, deaths, testing, and vaccinations. In contrast, other regions may face challenges in data collection and reporting, leading to potential data gaps or inconsistencies.

The availability of data can also be influenced by factors such as governmental policies, healthcare infrastructure, and resources allocated to data collection and reporting. Some countries may have established robust surveillance systems and well-defined reporting mechanisms, resulting in more comprehensive and reliable data. On the other hand, countries facing resource constraints or other operational challenges may experience limitations in data availability and quality.

This very dataset was recommended because Our World in Data takes significant efforts to gather data from various sources, including official government reports, public health agencies, international organisations, and research institutions, that's why Our World in Data's repository provides a solid foundation for examining and visualising the global COVID-19 pandemic. [12]

3.3. Key variables and attributes

The Our World in Data (OWID) GitHub repository for COVID-19 data contains multiple datasets. Here, I will be focusing on the primary owid-covid-data.csv file, which is a country-level dataset updated daily and includes various indicators related to the pandemic.

There were 47 variables, for this work there were 8 needed ones. [11]

Below is a brief description of chosen variables from the dataset:

Variable	Description

iso_code	SO 3166-1 alpha-3 - three-letter country codes.
continent	Geographical continent of the location.
location	Geographical location.
date	Date of observation.
total_cases	Total confirmed cases of COVID-19.
total_deaths	Total deaths attributed to COVID-19.
total_cases_per_million	Total confirmed cases of COVID-19 per 1,000,000 people.
total_deaths_per_million	Total deaths attributed to COVID-19 per 1,000,000 people.

4. ArcGIS temporal mapping techniques

4.1. Justification for using ArcGIS Pro

The choice of using ArcGIS Pro for visualising temporal data in the work has few reasons. Firstly, ArcGIS Pro offers an user-friendly GIS interface that enables the efficient handling of spatial data. In terms of COVID-19 data, this can include geolocational attributes such as countries, cities, or even specific healthcare facilities.

Secondly, ArcGIS Pro is renowned for its temporal data capabilities. The platform allows for the creation of dynamic visualisations which can display how the COVID-19 pandemic has evolved over time.

Finally, the software's interoperability makes it a versatile tool for any specialist. ArcGIS Pro can effectively communicate with various databases and data formats, enabling it to integrate easily into diverse research methodologies.

4.2. Main characteristics of ArcGIS Pro

ArcGIS Pro is a leading desktop GIS application, providing robust features that support data visualisation, analysis, and management. Its main characteristics include:

- **2D and 3D visualisation:** ArcGIS Pro allows users to create maps and models in both two-dimensional and three-dimensional environments. This versatility is particularly valuable for exploring complex phenomena, such as the spread of a global pandemic, where a 3D view can reveal hidden patterns and relationships.

- **Advanced spatial and temporal analysis:** The platform boasts a robust suite of analytical tools designed for both spatial and temporal data. These tools empower researchers to identify trends and patterns across geographic locations and over time periods. This is crucial for analysing the spread of infectious diseases like COVID-19, where understanding the spatial and temporal dynamics is paramount.

- **Project-based workflow:** ArcGIS Pro organises all project resources, including maps, layouts, data tables, and tools, within a single project file. This centralised approach streamlines workflow and simplifies project management, ensuring all necessary components are readily accessible.

- **Advanced symbology and representation**: ArcGIS Pro provides extensive symbology options, enabling users to represent data in a visually compelling and informative manner.

4.3. Temporal data visualisation methods in ArcGIS Pro

To track how COVID-19 spreads across the globe, we need to understand its spatial and temporal evolution thoroughly. Using ArcGIS Pro's temporal data visualisation tools, we can map out the pandemic's progression over time with precision. This allows us to understand its patterns and gain valuable insights. These visualisations are essential for policymakers and health professionals to keep an eye on the virus's path, identify trends, and plan effective responses. Here are the main methods used for temporal data visualisation in ArcGIS Pro.

Time-enabled Layers: One of the essential features of ArcGIS Pro for temporal data visualisation is the time-enabled layer. Time-enabled layers can manage and display geographic data at different moments. In the context of COVID-19, it means we can examine the same location at different periods, revealing how infection rates have changed over time.

Time Slider Tool: The Time Slider tool offers an intuitive interface for visualising and manipulating temporal data. By dragging the slider across a timeline, one can 'play' the evolution of the pandemic, revealing a cinematic portrayal of how the situation has unfolded. This dynamic temporal control enables the researchers to trace the proliferation of COVID-19 cases across the globe at varying speeds, facilitating in-depth temporal analysis.

Temporal Rendering: ArcGIS Pro provides options to apply temporal rendering to layers. This powerful feature allows users to represent the variation in intensity of an event over time. For instance, rendering COVID-19 data could involve colour-coding regions based on the severity of infections at any given point in time. This method would effectively illustrate peaks and troughs in the data, demonstrating the rise and fall in infection rates, and facilitating the identification of hotspots.

Creating Time Series Charts: Time Series Charts are an indispensable tool for revealing trends and patterns in data over specific periods. These charts offer a clear visual representation of data points indexed in time order, thus providing an overarching view of the pandemic's progression. For COVID-19, this could encompass daily new cases, cumulative case counts, recoveries, or death rates over time.

Each of these temporal visualisation methods provides a unique lens through which to understand the evolving nature of the COVID-19 pandemic. The capacity to engage with the data in these different ways enhances our understanding of the virus's behaviour and allows us to plan and strategize effectively for the future.

5. Visualising data with time slider and creating an animation

For the thesis it was needed to visualise the spread of certain COVID-19 aspects with the help of one of possible methods. After some research it was decided to try the animation method.

Incorporating the temporal dimension of COVID-19 case data allows the creation of time-lapse animations that show trends and patterns over time. These animations can be particularly useful for:

- identifying hotspots;
- understanding transmission patterns;
- communicating trends to the public.

The process of creating a time-lapse animation typically has several key steps:

— Data preparation:

Ensuring the data includes a time component with consistent time steps. The size of the time step can impact file size and animation smoothness. Larger datasets with smaller time steps may require optimization to avoid performance issues. In this case reducing daily data to weekly data.

— The raster layer representing all geographic units (e.g., countries) should have the same location or value names. Standardising names is crucial for accurate data joining.

— Temporal data integration:

Joining the temporal data file containing information to the geographical raster layer. This process joins in my case COVID-19 data with specific locations over time.

The exact steps will be described in the example of creating the animation in ArcGis Pro.

5.1 Preparing the data and importing to ArcGIS

In this thesis, the data preprocessing and cleaning procedures involved transforming the downloaded dataset, initially provided in an CSV file format, into a format compatible with ArcGIS for visualisation and analysis. This process required cleaning and transformation steps to ensure data consistency and integrity.

Upon downloading the dataset, it consisted of data provided for every single day since the beginning of the pandemy which can be quite granular and may not be directly suitable for visualisation in ArcGIS due to a big dataset size.

In order to fix this, the first step was to choose which variables I keep for my work and which timing I want to have in my thesis. Therefore, for the dataset there were next variables chosen:

iso_code

continent

location

date

total_cases

total_deaths

total_cases_per_million

total_deaths_per_million

It was decided after reviewing the whole dataset and finding out that most of the variables have no value, since many countries haven't reported it. Therefore, for this type of work it is enough to have just a few main variables.

Next step was to fix the time range and time steps for my dataset. The recommendation was that the optimal step is a week for each variable. It was needed to clean the data in some way. It was completed by creating a filter in Excel and simply picking every 7th day in the dataset. The outcome was weekly data which was precise enough for the purpose of this project. Also there was an attempt to fill the dataset with needed values straight from Github with the help of AI tools, more will be explained in the discussion section.

By converting the data to a weekly format, it became more suitable for analysis and visualisation in ArcGIS.

Next step was filling all blank cells with zeros. There are few opportunities to do so, the easier one was filtering all blank cells and substituting them with zero values. In the end, the table looked like this:

	A	B	C	D	E	F	G	H
1	iso_code	continent	location	date	total_cases	total_deaths	total_cases_per_million	total_deaths_per_million
2	AFG	Asia	Afghanistan	09.01.2020	0	0	0	0
3	AFG	Asia	Afghanistan	16.01.2020	0	0	0	0
4	AFG	Asia	Afghanistan	23.01.2020	0	0	0	0
5	AFG	Asia	Afghanistan	30.01.2020	0	0	0	0
6	AFG	Asia	Afghanistan	06.02.2020	0	0	0	0
7	AFG	Asia	Afghanistan	13.02.2020	0	0	0	0
8	AFG	Asia	Afghanistan	20.02.2020	0	0	0	0
9	AFG	Asia	Afghanistan	27.02.2020	1	0	0,024	0
10	AFG	Asia	Afghanistan	05.03.2020	1	0	0,024	0
11	AFG	Asia	Afghanistan	12.03.2020	7	0	0,17	0
12	AFG	Asia	Afghanistan	19.03.2020	22	0	0,535	0
13	AFG	Asia	Afghanistan	26.03.2020	74	1	1,799	0,024
14	AFG	Asia	Afghanistan	02.04.2020	192	4	4,668	0,097
15	AFG	Asia	Afghanistan	09.04.2020	423	14	10,285	0,34
16	AFG	Asia	Afghanistan	16.04.2020	721	25	17,53	0,608
17	AFG	Asia	Afghanistan	23.04.2020	1092	36	26,551	0,875
18	AFG	Asia	Afghanistan	30.04.2020	1827	60	44,421	1,459
19	AFG	Asia	Afghanistan	07.05.2020	3224	95	78,388	2,31
20	AFG	Asia	Afghanistan	14.05.2020	4967	127	120,767	3,088
21	AFG	Asia	Afghanistan	21.05.2020	7653	177	186,074	4,304

Image 6: Filtering data to weekly steps

The next step was finding a suitable world map dataset. After reviewing a few, the biggest issue was to find one that will include all independent territories also, so both datasets can be joined right.

After researching datasets the choice was one that was provided by ArcGIS official website. After uploading a shapefile to the new project in ArcGis, there was a primary comparison.

Next step would be to connect prepared tables with Covid-19 data, and join it to the world map layer, but first it made sense to compare country names provided by ArcGis and Covid-19 data - country and territory names would vary and it could complicate the further work. For that purpose was used Chat GPT with a prompt:
"compare 2 lists of countries from 2 different datasets and show me unique values in both datasets. Output in a table: *List 1* *List 2*".
The output was unique values of country/territory names that don't match and would not be joined.

The most common ones were islands that belong to a certain country, ArcGis dataset distinguished them and the World in maps dataset not, so It was fixed it till it was like this:

Before:

Image 7: Dataset before standardising location names

After:

Image 8: Dataset after standardising location names

The unique values were removed: they were data for whole continents and for middle, upper, and low classes.

Both files were imported in the same dataset so there can be implemented one-to-many join, and joined the table to the layer, which was successful. Then as a basemap map was picked the National Geographic one - for the better visual look.

5.2. Enabling time on the layer and symbolising the data

After the successful both datasets preparing and joining, there could be enabled time on the layer.

First, the "Select by Attributes" tool was used to create separate layers for Europe and Africa: this made the visualisation process faster and easier.

The Dot Density method was chosen for symbolising the variables "Total cases" and "Total deaths." The Graduated Colours method was chosen for "Total cases per million" and "Total deaths per million."

Generally the process has next steps:

- labelling and adjustment;
- symbology and adjustment;
- finding the right bookmark;
- time slider enabling;
- creating an animation and adding dynamic texts;
- creating legends;
- exporting an animation;
- last animation editing.

After that, country names were needed on the map in English, so labelling the map was necessary. All country names needed to be visible, preferably inside polygons. According to the ArcGIS documentation, label positions were generated automatically, they were not selectable, and individual labels were not editable. [19]

In order to be able to make labels editable they should be converted to annotations:
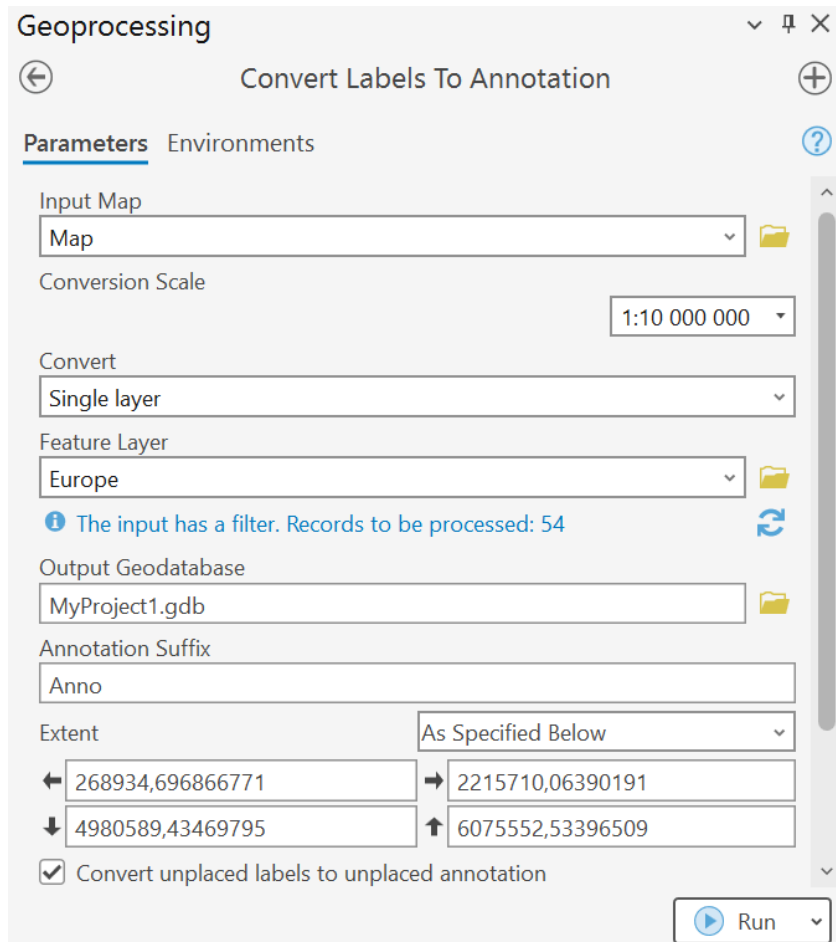
Image 9: Labels to Annotations conversion

Then all labels were placed manually until it looked visually appealing, with all country names positioned horizontally, preferably inside the polygons. Different fonts and sizes were tested until the labelling was satisfying. Some smaller country names, like Luxembourg and Liechtenstein, were placed and adjusted manually.

Image 10: Map after adjusting annotations

After that, symbology can be enabled. Settings can vary depending on the aim and the map, for example for visualising total deaths cases over time in Africa with the help of Dot density method, it is clear that the bigger value the dot has the less informative the map will be, and for Europe small dot values can create the data overload.

Symbology also needed a lot of visual adjustment. For example default colour palette for Graduated colours method should be adjusted, the recommended tool is ColorBrewer. [23]

The most of the experiments were with fixing the bookmark for export. The map view before and after export is different, meaning in the ArcGIS Pro the map view is influenced by other enabled tables and windows like Catalog Pane in the program, so the for the right position it should be used the preview frame tool:
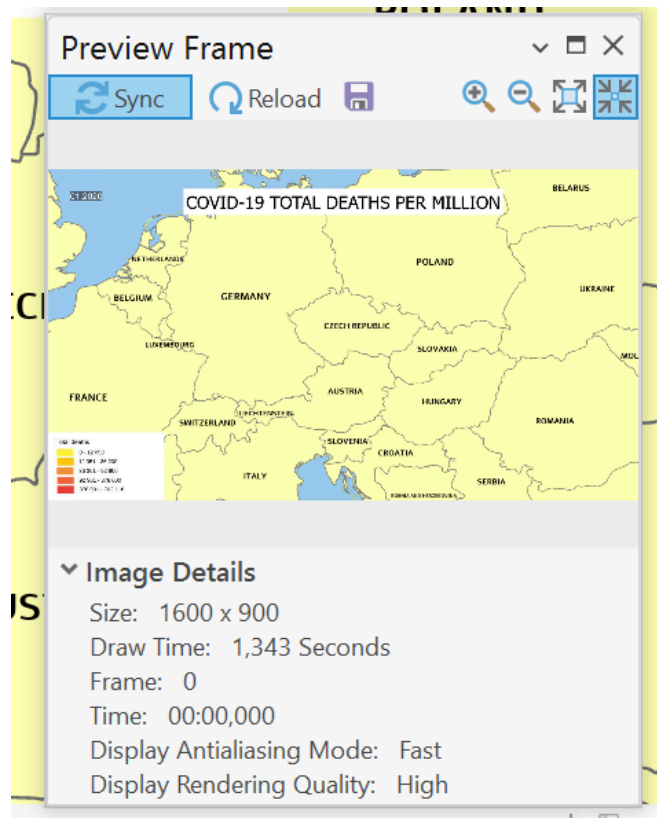
Image 11: Preview frame tool

It gives a clear look on how the animation will look after export. Once the bookmark is saved it can be used for all animations during the work.

After that there can be enabled time for the layer by specifying the temporal field (dates).
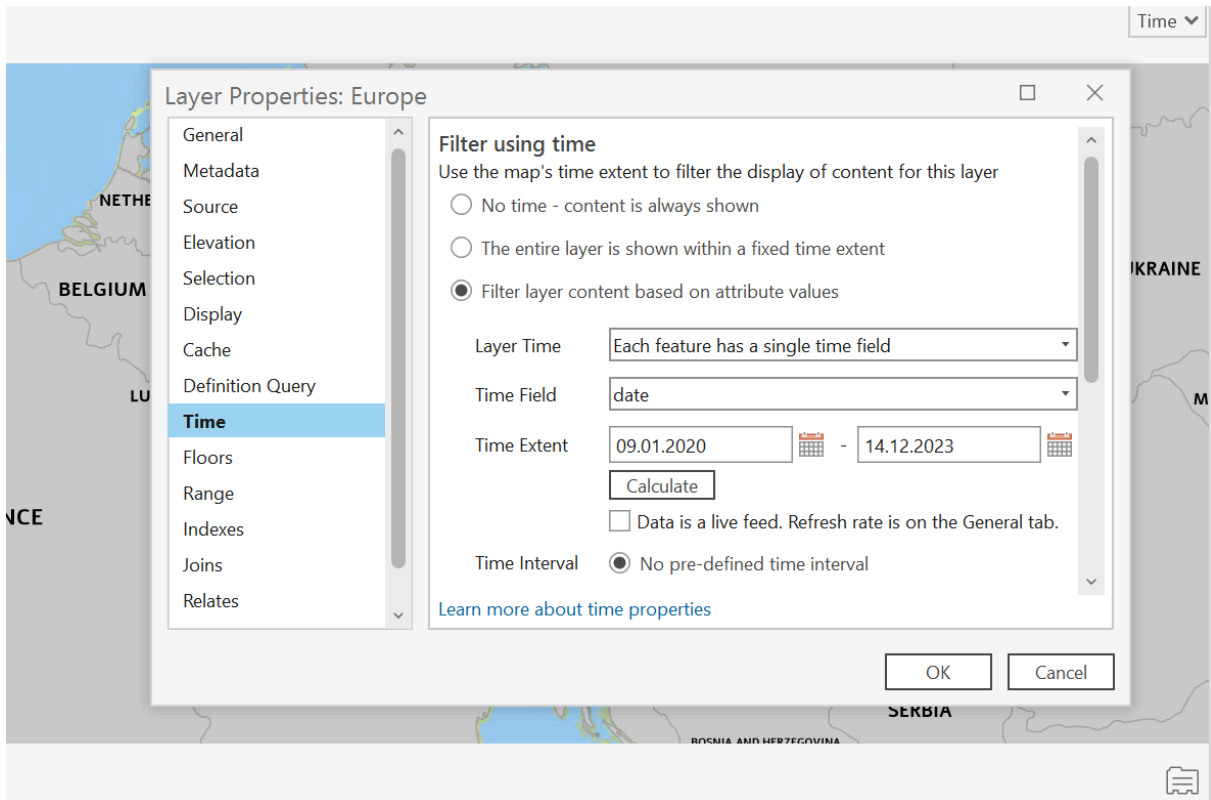
Image 12: Enabling time for the layer

For further animation export there were adjusted all the time settings: defined the time step, 1 month for this work, start and end time. After that the time slider was enabled and all needed values over time were visualised.

While moving the time slider the map was changing according to the values in time which means it was done right and creating the animation and exporting it can be done next.

5.3. Creating an animation

Next step is creating an animation. Newer ArcGIS version offers to create more animation types and for certain platforms like YouTube, but the basic ones are .avi, .gif, .mp3. For this project it was decided to create .gif format animations.

The monthly snaps would be enough for this type of work, but it is possible to define any needed time steps. After defining time steps, start and the end date all

keyframes can be exported automatically to the animation timeline by Import - Time Slider Steps tool.

The problem was to add a legend to animations, ArcGIS documented just some solutions for adding map time and dynamic texts to be displayed in a desired way. Overlays that could be used are map title, the date and the shape where the legend will be inserted. In ArcGis Pro the legend can not be generated automatically like for the layout, so it should be prepared with the help of external tools, like Canva. It is convenient to create a legend template there and use it for all animations afterwards. [16]
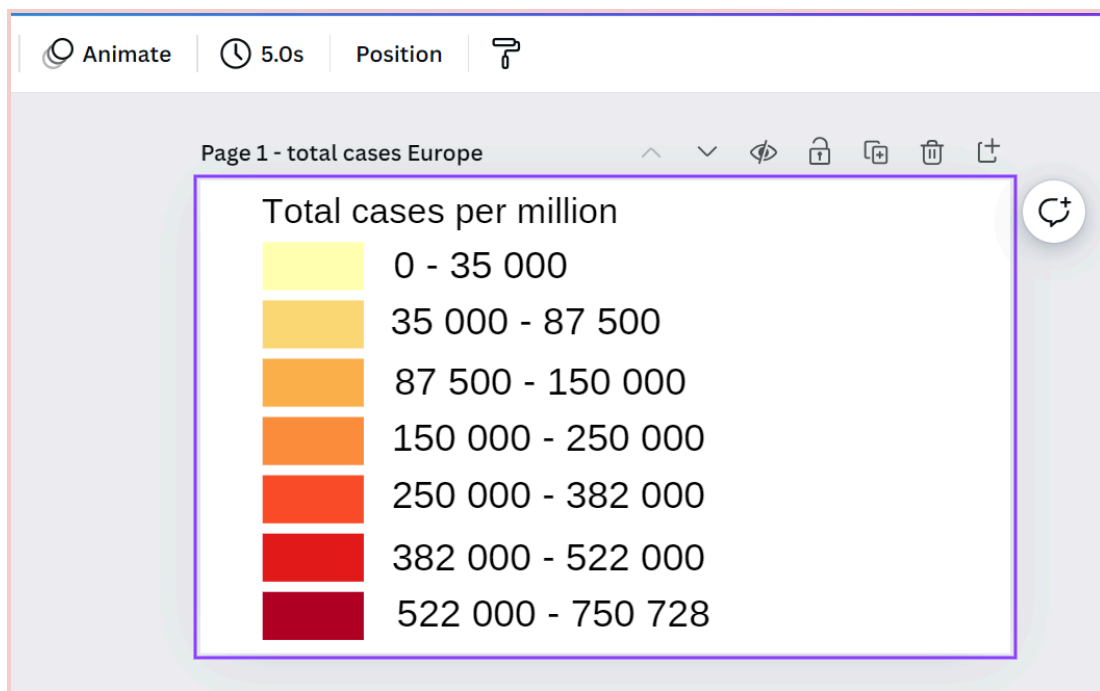
Image 13: Creating a legend template in Canva

ArcGis Pro allows to edit dynamic texts: font, size, background, placement, also placement on the timeline. For the Map Time dynamic text there are few options of formats, for monthly data the most suitable one was: *<dyn type="animation"*
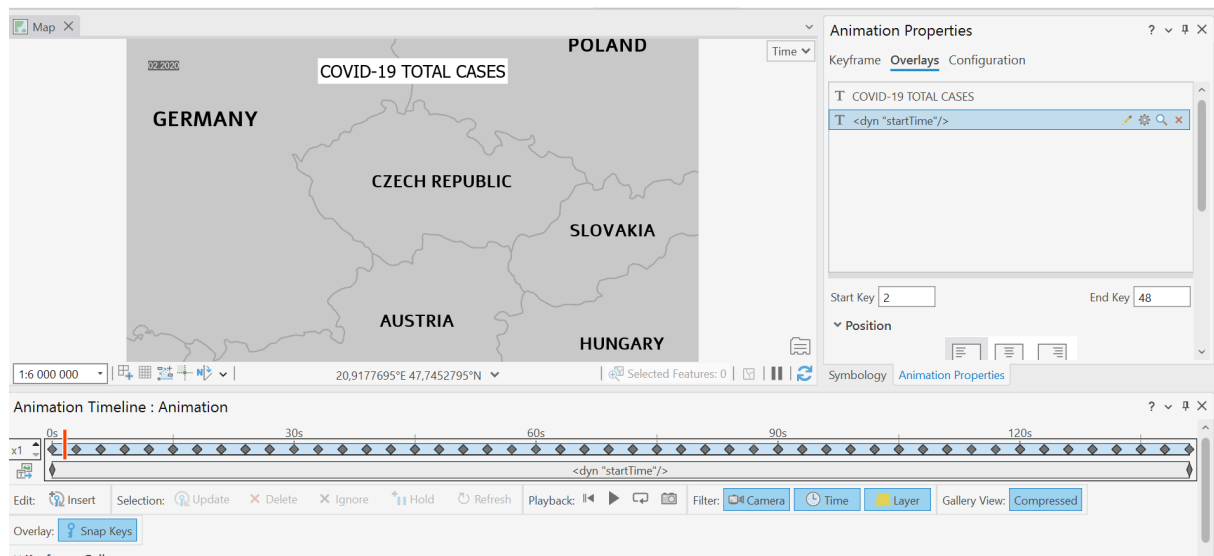
property="startTime" format="MM/yyyy"/>

Image 14: Enabling dynamic texts

Inserted a square shape or already created legend by external tools can allow adjusting country names so it will not overlap.

After making sure that animation is looking according to all expectations, the animation can be exported. Export parameters were:

Format: GIF;

Frames per second: 2;

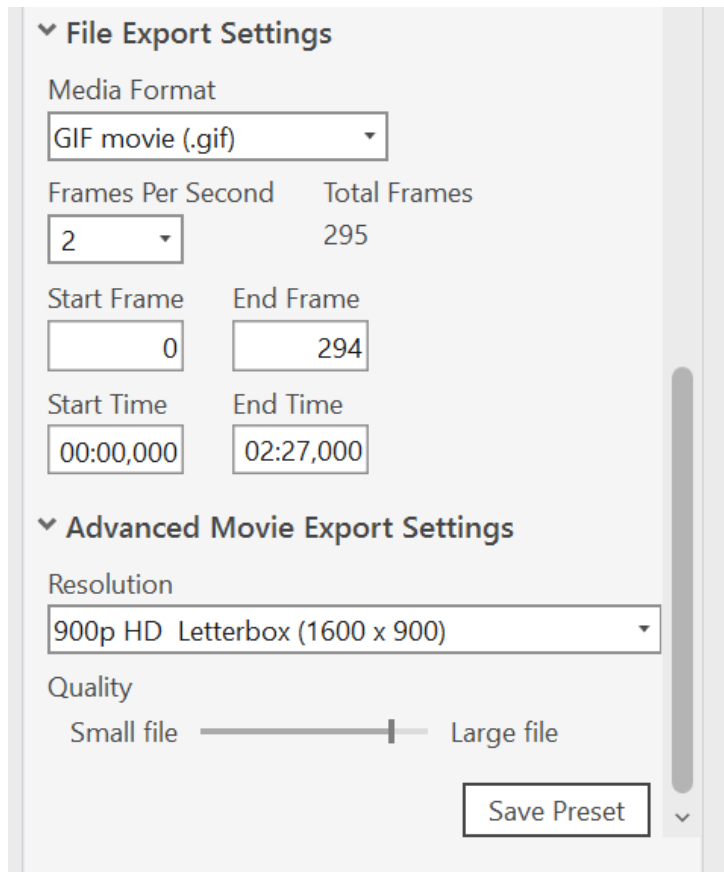Resolution: 1600x900;

Quality: large file.

Image 15: Animation export parameters

ArcGIS does not provide the opportunity to edit animations in any other way, so for adding legends, changing speed and other needed actions the most convenient was Clipchamp program, since it leaves no watermark, it is free and easy to use and it allows to connect other accounts: OneDrive, YouTube etc. It can be used for speeding up and inserting needed images. [24]

The final animations could not be attached neither to the file nor to the whole work, so they can be found in One Drive folder with a free access:

https://1drv.ms/f/s!AiJMCjdZoexOgQOmZOabkuwjqIIq?e=waqLhN
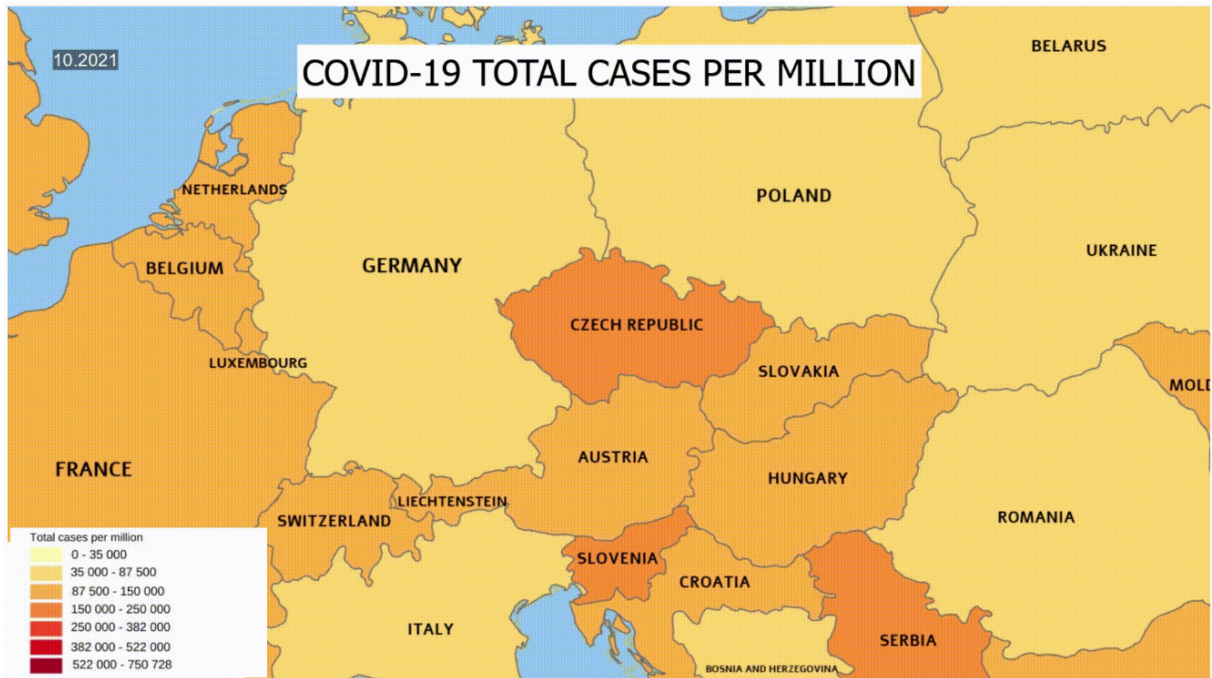
There are examples of final animations:

Image 16: Final animation of COVID-19 total cases per million in Central Europe

Image17: Final animation of COVID-19 total cases in Central Europe

6. Discussion

While working on the thesis the first hard part was preparing the data. As already mentioned, the data was taken from Github. The dataset was too big to manipulate it easily, so just for personal curiosity I wanted to fill my Google sheets straight from Github with the help of AI extensions. It would be possible to define the time steps I need for my work and that would save me much time filtering data almost manually. Unfortunately after a few experiments due to lack of instructions and my technical skills this attempt failed. In the time of AI taking over there can be a way and some clear instructions how to implement it in working with data and I believe it could be innovative and save lot's of time. AI can be also implemented to create graphics or

During my work I saw the gap of clear step-by-step instructions. For example, it took some time to realise why the animated map before and after the export looks different, before I used all the tools and experimented by myself. I think more explanations and more documentation would give the average student more encouragement for making projects and generally involving into GIS works.

During creating animated maps, there was a problem of further video editing, or creating legends before the map export and separately, since it is not possible to do it automatically in ArcGIS Pro. It is possible for the layout, but not possible for the animation which can bring some difficulties.

7. Conclusion

The thesis explored the creation of time-lapse animations in ArcGis Pro to visualise and understand the spread of COVID-19 around the world. It highlighted the importance of using clear and consistent data visualisation techniques, particularly when working with temporal data. The dataset provided by Our World in Data was tested, there were also tested methods to clean the data manually versus automatically.

During the research it was found out the main difficulties that may occur during mapping big-scale events. A lot of maps are inconsistent, not informative and not-user friendly because of data problems at the first place.

Generally the whole process of creating the time-lapse animation was tested and as an outcome there are 9 animations displaying developing COVID-19 aspects over time in Central Europe, Africa and one for total deaths per million worldwide for countries with top-10 highest values.

During the work on the thesis it was highlighted that the biggest scope of work on the time-lapse creation was preparing data and visually editing the map and video after export. Here was seen an opportunity to implement AI tools to automatize the whole process and save time. Due to ArcGis Pro lacking some video editing opportunities like changing the speed or adding needed elements to the animation there were tested few external tools the most suitable for this work.

8. Literature and sources

8.1 Literature

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8.2 List of images