Visualization of COVID-19 incidences and treatment capacities with CoronaVis

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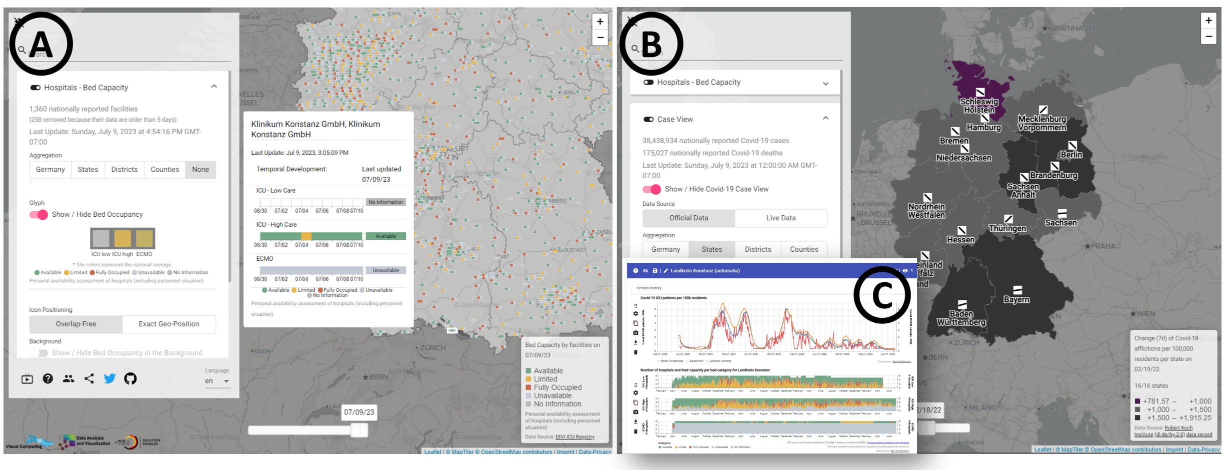

Figure 1: CoronaVis shows ICU capacities in three categories (low-care, high-care, ECMO) for individual hospitals on a map (A). COVID-19 statistics, such as the 7-day-incidence, are displayed as choropleth maps where glyphs indicate the current trend (B). Information from both views, A and B, can be overlaid. The user can create and share individual dashboards that allow for comparing different regions and COVID-19-related variables (C).

Abstract

The COVID-19 pandemic and its rapid development within a few weeks place completely new demands on the analysis of infection statistics. CoronaVis provides interactive visualizations through which case incidences and bed capacities of intensive care units (ICUs) across Germany can be analyzed. CoronaVis is primarily designed to support physicians, crisis teams, and medical decision-makers and to enable informed decisions, for example, on patient distribution in the event of impending overload. CoronaVis scales from the local to the national level through flexible aggregation capabilities. This paper introduces the analytics capabilities of CoronaVis and takes a closer look at the power of interactive visualizations in supporting dynamic situations.

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1 Introduction

CoronaVis[1] is publicly available and was created at the onset of the COVID-19 pandemic in March 2020, after a chief physician from the Konstanz Hospital approached our research group with a support request. Just a week before the request, news from Bergamo, Italy, captured attention when several regional hospitals were overloaded, resulting in many deaths. The local proximity to the region raised concern among physicians in southern Germany. The clinic's decision-makers became aware that the existing information systems and statistical sources to prepare for the impending patient numbers were insufficient. They, therefore, asked for the development of an overview solution, which can show the treatment capacities of the hospitals on a large, detailed scale and be able to put these in the context of the developing case numbers to be able to react to waves of patients and impending overloads of the intensive care units (ICUs). This request resulted in a prototype developed within three days, on which today's CoronaVis is based. In contrast to the

[1] http://coronavis.dbvis.de

normal approach, a fast and productively usable system that can be scaled to several thousand users simultaneously was created quickly.

2 Target Users and Requirements

The user base grew organically. The first target users were medical experts. Then crisis management experts stated their interest in the tool, followed by policymakers and the public.

Medical experts and physicians: CoronaVis was initiated by this user group. Users in this group work at a detailed level, focusing on the hospital where they work. In some cases where hospitals have multiple locations, this can be extended to a few regional hospitals. The most important use case is planning for many new patients that need to be admitted as inpatients and transferring patients in case the local hospital does not have enough ICU beds.

Crisis management teams: These teams operate at different administrative levels due to the hierarchical administrative structure. At the local level, some medical experts are members of the teams, while at higher levels, such as the district or state level, the crisis teams operate more detached from the medical care facilities. Their main task in terms of ICU capacity is the early detection of local outbreaks and subsequent bottlenecks and the distribution of patients to prevent hospital overload within a region.

Policymakers: These users are mostly interested in aggregate statistics from the county to the national level. Individual hospitals are less of a focus here, while interest tends to focus on spatial and temporal comparisons that can show the impact of policy decisions such as Corona ordinances. At the federal level, such policies can vary widely across regions, and CoronaVis can help visualize the impacts.

Media and public: This is the fuzziest user group, with information interests at all levels of aggregation. Citizens or the media may be interested in conditions at the local hospital but at the same time also interested in the nationwide situation. For this to happen, the system provided must be intuitive and easy to understand. Relevant information must be presented immediately or with little effort.

A general requirement is that CoronaVis must be usable and understandable with little to no training, as most users are not in direct contact with the developers. On the other hand, it must be complex enough to allow for the different user groups' various usage scenarios and requirements. In hindsight of a possible crisis, the visualizations must be intuitive and fast to grasp. The app was also expected to work on as many devices as possible, including smartphones, tablets, laptops, and on larger screens. Furthermore, the app must be available, scalable, and provide reliable information. This would not allow us to make breaking changes during the development.

3 Development Process

Initially, the development occurred in fast iterations, and subteams were formed to tackle specific (design-) challenges. Each team would individually implement their designs into the prototype, and multiple times per day, the whole team would meet, check on the progress, evaluate designs, and discuss how to progress further. Competing design teams have tackled a similar challenge, where the whole team would decide on a winner. The first prototype was presented to the medical staff at the hospital after just three days.

The prototype's positive feedback and immediate use encouraged us to continue developing. However, the fast pace in the first two weeks was not sustainable, and eventually, the development cycles became longer, and fewer team members could dedicate as much time to the project. Nevertheless, the app has been maintained, and features have been continuously added throughout the years.

The initial target users were expanded to crisis management teams, where developers participated in staff meetings. Eventually, through print- and social media, politicians and the general public became aware of the app, and the visits increased to several thousand per day, peaking at 30,000 per day. As the app is open-source [2] users would actively approach us via email, Twitter, and GitHub issues raising problems and wishes for further features.

4 Current System

A central aspect of the app is the map view that displays ICU capacities of individual hospitals. Glyphs are displayed on the map (see Fig. 1 (A)) where each of the three colored rectangles represents the categories: icu-low (no invasive ventilation), icu-high (invasive ventilation), and ECMO (extracorporeal membrane oxygenation). To avoid overlap, the glyphs re-arrange themselves using a force-based physics simulation. For each category, there are states (available, limited, fully occupied, unavailable) provided that each hospital publishes individually and daily [3]. A tooltip provides the historical data for each hospital. The data can be aggregated on a county, district, state, and country level, merging the glyphs and visually averaging the colors. While the information on the ICU capacities is publicly available, no other visualization shows that information in a spatial context for individual hospitals.

Similarly, COVID-19 statistics, such as the 7-day-incidence, a 7-day rolling average, can be displayed as a choropleth map (Fig. 1 (B)). This design is familiar to users and widely used. We extended the design by adding glyphs as white rectangles containing a straight black line indicating the trend of the statistic in the particular region. The trend is derived using linear regression. This design is non-obtrusive, and even if the user does not first understand the glyph's purpose or ignores it, the choropleth map can be interpreted as usual. CoronaVis allows overlaying the ICU capacity glyphs over the choropleth map, rendering the trend glyphs invisible. This provides context for ICU capacities with current COVID-19 statistics, which may be important for decision-making. Details for each region can be accessed via a tooltip and a dialog window showing a table for each variable, as well as line charts and pixel charts for a temporal statistic.

Users can create individual dashboards. The user can create charts that show various statistics over time. Multiple regions can be added, resulting in multi-series line charts allowing to compare the regions. For other types of charts, the values are aggregated. The charts can be freely ordered, and additional markdown blocks can be added to provide a description or explanation for the dashboard. To avoid any user-based access to the app, no dashboard can be modified, but each modification and save action results in a new dashboard where the history of each dashboard is visible on top in a tree-based design. The creation of dashboards is dedicated to more experienced users. However, the learning curve is flattened by allowing to extend on available dashboards as well as providing default dashboards for each region that can be extended respectively. Users have created over 10,000 dashboards. Several thousand daily visits (averaged) from 2020 to 2022 were registered.

CoronaVis has received a lot of positive feedback, and we received many requests for features we could not implement due to time constraints. At the same time, the general interest in the pandemic has vastly decreased. Yet, CoronaVis is a good basis for any pandemic or endemic use case and could quickly be adapted to new data sources and regions worldwide.

[2] `https://github.com/dbvis-ukon/coronavis`
[3] `https://www.intensivregister.de`