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AScore – Developing a Cockpit for Regional Pandemic Management in Germany with Agent-Based Social Simulation

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1 ABSTRACT

Managing the COVID-19 pandemic is a major challenge for decision-makers in crisis staffs, especially on a regional level. Decisions on intervention measures to contain a pandemic must be made promptly and under uncertainty. The project AScore aims at supporting decision-makers by means of an information management cockpit that intertwines smart city technologies and agent-based simulation. This paper introduces the project, outlines the concept and architecture of that cockpit, and presents first use cases and results. It shows what data and analysis functionality is important in pandemic crisis management and how social simulation can inform decision-makers about what intervention measures to put in place for containing a pandemic on a local level–as well as when and how to lift them.

Keywords: Digital Twin, Smart City, Agent-Based Social Simulation, Pandemic Management, Dashboard

2 INTRODUCTION

Managing the COVID-19 pandemic is a major challenge for leaders and decision-makers at different levels of societies. The main reason for this is that the pandemic affects multiple dimensions of human life, that there are numerous conflicting goals, and that responsibilities are often distributed or unclear. Decisions on intervention measures to contain a pandemic must be made promptly and under great uncertainty. In Germany, federal and state governments set the framework for containment of the escalating infection disease following the Pandemic Plans on federal and state level as well as the German Infection Protection Act. However, districts and their health authorities are responsible for implementating specific measures at the local level to meet federal or state decisions. Thus, municipal crisis management at the county level, with implementation regulations, monitoring of compliance with measures and, if necessary, setting additional county-specific measures, plays a crucial role. This pandemic management must balance the often competing demands of (1) avoiding overload of the local healthcare system, (2) fulfilling social, cultural, and economic needs, (3) maintaining availability of critical infrastructures, as well as (4) protecting public health. This task cannot and must not be carried out "blindly". Rather, it is necessary to have access to decision-relevant data, information, and knowledge about the four areas of demand listed above.

During an escalating infectious disease, this data and information situation, as well as its reliability, precision, or uncertainty, changes constantly: If it is initially uncertain and incomplete, "better" data and new knowledge about the respective disease become available with increasing time. In the rarest of cases, this information is available at the municipal level in a way that supports efficient crisis management. This reveals the current information management dilemma in crisis management: While there is an objectively high demand for information, it is met only inadequately with the existing municipal information systems. The main objective of the AScore project presented here is the design and development of a simulation-based management cockpit for municipal crisis management in the event of escalating infectious diseases. Using the example of the municipality of Kaiserslautern and the COVID-19-Pandemic, AScore employs methods from the field of Artificial Intelligence (AI), particularly smart cities technologies and agent-based social simulation.

In the following, we will first introduce the innovative approach to information management by combining available information of smart cities and agent-based social simulation for infectious disease control. The AScore project, information demands as well as the technical architecture, findings of requirements analysis as well as first steps towards a management cockpit will then be presented. Additionally use cases are discussed for demonstrating the utility of our approach and to identify challenges when integrating, analyzing, and visualizing data for decision makers. The paper concludes with a summary and an outlook on future work.

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3 COMBINING SMART CITIES TECHNOLOGIES AND AGENT-BASED SOCIAL SIMULATION FOR REGIONAL PANDEMIC MANAGEMENT

At its core, the AScore project presented in this paper builds upon the foundation of combining smart cities technologies with agent-based social simulation. This approach, while being innovative, is not entirely new. In fact, one fruitful combination of those technologies is demonstrated by the well-known CityScope project for urban planning by the MIT Media Lab City Science group (Alonso et al. 2018).[1] In CityScope, city data, analysis tools, and visualization as used in smart cities projects are combined with an agent-based simulation framework as well as participation elements to allow for interactive and dynamic urban planning. The key innovation here is to interleave static analysis and dynamic simulation in order to provide process-oriented insights into possible changes in the city that follow planning decisions.

Without a dynamic component, it is difficult to anticipate the effects of decisions in a changing world. This is also the case for crisis management in the context of COVID-19. Since the outbreak of COVID-19, various information platforms, data repositories and dashboards have been developed.[2] Most of these monitor the disease on an international or national level. Fewer examples cover individual municipalities, and in many cases, these platforms have a particular focus (e.g., monitoring the number of reported COVID cases, reporting the progress of vaccination campaigns, or informing about interventions put in place in order to contain the pandemic). Nonetheless, these platforms utilize a number of techniques that have been developed in the context of smart cities: Spatiotemporal data retrieval and aggregation methods, storage solutions and analysis workflows, as well as visualization and dashboarding frameworks. And some examples even include a dynamic component which uses simulation to forecast possible future developments and compare different counter-pandemic strategies (e.g., Bortz et al. 2020, Dings et al. 2021).

Such forecasts and comparisons are a valuable tool for decision-makers in crisis management. In an ever-changing crisis situation, it is necessary to anticipate what is likely to happen because available data is always delayed and the effects of decisions will only fully unfold at a future point in time. Consequently, decision-makers have to extrapolate on their available information and decide on potential interventions even before these appear to become necessary. Moreover, they have to strike a balance between the expected benefits of interventions on the pandemic situation and the restrictions they impose on the economy, social and cultural live, and the individual freedom of the population. To that end, the aforementioned tools to compare different available intervention measures are valuable assets for supporting crisis managers.

However, the majority of crisis management responsibilities (at least in Germany) are located on a regional and local level. Each municipality has its local crisis management staff, often led by the local mayor and consisting of experts in the affected public fields (e.g., hospital managers, regulatory and health authorities, fire fighters and civil protection agencies, education and other public service authorities). These members of a crisis staff face the challenge to decide about local measures and make their decisions dependent on the respective local situation. They also have their individual perspectives for interpreting that situation and their specific data sources upon which they base their interpretations. For instance, crisis staff and local council members may have to decide which sports facilities can be opened or need to be closed in order to allow for leisure activities while avoidung to expose the population to unnecessary risks of infection. Supporting this type of decision-making requires tools that focus on the pandemic situation in a particular region, that provide detailed analysis functionalities to compare localized intervention measures, and that allow for integrating analyzes from different perspectives and fields of expertise.

To achieve those three goals, the AScore project complements the existing platforms described above with a localized equivalent that is geared towards regional crisis management. This requires collecting and analyzing data about individual municipalities and modelling local intervention measures in detail for simulation purposes. To that end, existing technologies developed at DFKI are newly combined and extended. On the one hand, data sources about the local population, infrastructure, and public services are

[1] See also https://cityscope.media.mit.edu/ and https://www.media.mit.edu/projects/cityscope/overview/

[2] Examples include, but are not limited to the following platforms: WHO Coronavirus (COVID-19) Dashboard (https://covid19.who.int/), COVID-19 Dashboard by CSSE at Johns Hopkins University (https://coronavirus.jhu.edu/map.html), RKI COVID-19-Dashboard (https://experience.arcgis.com/experience/478220a4c454480e823b17327b2bf1d4/), Bundesministerium für Gesundheit Impfdashboard (https://impfdashboard.de)

made accessible to crisis managers. Using smart cities analytics tools, that data is aggregated and visualized to enable assessments of the actual pandemic situation. This analysis takes various perspectives into account in order to provide a more comprehensive view on that situation. For instance, not only numbers of reported infections are considered, but also the impact of intervention measures on the local economy and public life can be visualized. On the other hand, agent-based social simulation is used to model the behavior and daily routines of the local population and to analyze impacts of intervention measures that have not yet been applied. In AScore, the agent-based model utilizes the aforementioned data to build a digital twin of the municipality in focus. Individual persons are being represented in the simulation by agents that act in a typical manner, e.g., according to a person's age. The model also contains a disease component to represent a potential spread of COVID-19 across the population. Additionally, public and private infrastructure is represented in the model such that the utilization of facilities by agents and the impact of intervention measures (e.g., lockdowns) can be simulated. In this way, AScore brings together DFKI's smart cities toolkit with its agent-based simulation technology developed under the term "Social Simulation for Analysis of Infectious Desease Control" (SoSAD).

SoSAD is an agent-based simulation model based on real-world smart city information and data. It has been in development at DFKI and Trier University since early 2020. In this model, all persons of a population are modeled as agents with their respective family relationships and typical daily routines. The daily routines include occupation, school attendance or leisure activities, during which agents can meet. Combined with a disease model (for COVID-19), the spread of an infectious disease can be simulated depending on the activities of the population. This in turn allows for modeling pandemic control measures that restrict certain activities (e.g., closing schools) and thus change rates and possibilities of infectious contacts. By means of systematical simulation, these measures can be compared with respect to their intended effectiveness as well as potential unintended effects. The results can then be analyzed in the same way as real-world data is handled. In AScore, this provides decision-makers with information about hypothetical developments (what-if-analyzes) to complement information about the current actual situation (what-is-analyzes).

Each agent in SoSAD is a digital twin of an individual person of a particular age in years, a demographic information that is retrieved from the AScore data storage. This allows for a detailed representation of cities and municipalities of up to several million inhabitants in the simulation. Depending on their age, the agents are clustered into three distinct behavioral groups with typical daily routines: Children (including adolescents), workers (including students), and pensioners (i.e., all agents above the age of retirement). Similar to other agent-based modeling approaches (e.g., Huang et al. 2005, Bicher et al. 2020), agents of each group frequent a number of particular locations where they can meet other agents. Workers have a workplace which can represent a private company, a public service agency, as well as a university or other higher education facility. Children instead go to school. Agents of any age have a home where they either live alone or together with other agents. Furthermore, all agents frequent leisure facilities which represent shops as suppliers of essential and non-essential goods as well as cinemas, gyms, stadiums and concert halls as well as any other public place for recreational activities. Real-world information about any of these locations is retrieved from the data storage to generate a digital twin of a particular city's infrastructure for the purpose of social simulation.

Two agents that frequent the same location can meet each other there. Since not every encounter will be potentially contagious, SoSAD only models those contacts that are sufficiently intense to spread the virus. In these instances, contagion takes place with a certain probability if one of the agents carries the virus and is infectious. This is the same basic principle as in most other agent-based COVID-19 contagion models (Lorig et al. 2021). The model of disease states and their progression is analogous to a modified SEIR approach as published by the Robert Koch Institute (RKI), the German government's central scientific institution for biomedicine and public health (an der Heiden & Buchholz 2020).

Any agent that has not yet been vaccinated or infected with the virus is susceptible to it (state S). If the virus is transmitted to such an agent, that agent becomes exposed (E). After a latency period, the agent becomes infectious for a period of time (I) during which it can infect other agents. In the case of COVID-19, an agent becomes infectious before it may develop symptoms of illness. There are six levels of symptoms, one of which is predefined for each agent according to a distribution as observed in sample studies of COVID-19 cases (e.g., Dong et al. 2020, Zhou et al 2020): asymptomatic, minor, moderate, severe, critical, and fatal. Depending on its symptom level, an agent will be unable to even recognize its infection without test, it may or may not stay at home, become hospitalized, require intensive care and eventually either recover or pass away. If agents stay at home or become hospitalized, they will no longer have contacts at work, school, leisure facilities, or at home. Recovered agents will become immune to further infection (R). The same holds for agents that have received vaccination. These become immune with a specific probability that depends on the vaccine's effectiveness.

In addition to vaccination, SoSAD implements several pharmaceutical and non-pharmaceutical interventions to control the simulated pandemic. These can either reduce the infection probability in case of a contact between agents (e.g., by wearing face masks or using air filtration) or the ability for an agent to even meet others (e.g., through contact restrictions and lockdowns). Agents become aware of activated interventions, and they can decide whether to follow the rules or whether to violate them. For instance, if leisure facilities have been closed, agents can still meet in private, and they decide for themselves if they wear protective masks on such an occasion or not. This allows for analyzes of interventions in the presence of non-conformant behavior. In AScore, a library of counter-pandemic measures is provided. Any combination of interventions forms a simulation scenario that can be compared with alternative scenarios in order to gain insights into possible regional strategies for containing the disease. Because implementing these measures can have impacts on, e.g., both the spread of the disease and the local economy (in case of a localized lockdown), such a comparison enables crisis managers to make informed decisions considering multiple perspectives on the situation. Making that functionality accessible to crisis managers is the main goal and the most important innovation of AScore.

4 THE ASCORE PROJECT

4.1 Project Context and Partners

AScore[3] is a consortium project funded from 01/2021 until 12/2021 within the framework of the special programme "Zivile Sicherheit – Forschungsansätze zur Aufarbeitung der Corona-Pandemie" by the German Federal Ministry of Education and Research (BMBF) under grant number 13N15663. AScore brings together partners from AI and smart cities research (DFKI GmbH), mathematical optimization and epidemiological simulation (Fraunhofer ITWM), data science for business (CID GmbH), as well as crisis management (VfS e.V. and mata:solutions GmbH). To realise pilot scenarios, the City Administration of Kaiserslautern joined the project as an associated partner. Transferability of the results is ensured by the City Administration of Trier being a second application partner.

4.2 General Vision of AScore

AScore aims at improving the crisis management such that decision-relevant information is available for assessing potential intervention measures to contain a pandemic. To this end, a cockpit is being designed and implemented, which covers the areas (1) avoiding overload of the local healthcare system, (2) fulfilling social, cultural, and economic needs, (3) maintaining availability of critical infrastructures, as well as (4) protecting public health. For these areas, real world data is collected, analyzed, and aggregated in a pandemic pressure scoring system to visualize and assess the current situation. The same process is also used for integrating synthetic data from simulations of what-if-scenarios, which compare possible effects of different intervention measures. The agent-based social simulation system SoSAD, developed at DFKI and adapted to the Kaiserslautern region, allows for implementing such measures on a detailed level and observing their effects on the interactions and, thus, infection dynamics within a realistically simulated population.

5 ASCORE APPROACH AND ARCHITECTURE

5.1 Information demands

Data in AScore is used for three main purposes:

(a) to provide information about the current status,

(b) as input for and output of the SoSAD Social Simulation, and

(c) as part of the measures-impact repository.

[3] See https://ascore.kl.dfki.de for more project information.

We will now discuss each of these purposes as well as the data involved in more detail.

5.1.1 Status Information

For all areas to be covered in the management cockpit, information about the status including important news or developments is required. This includes information about the citizens actually infected, capacities in the local health system, availability of critical infrastructure as well as information about impacts on social, cultural, and economic aspects. For all these areas, data sources need to be identified in close exchange with relevant stakeholders from the fields as well as from crisis management. In order to be able to make use of the data sources, a variety of tasks have to be solved. These range from technical accessibility to clarification of data protection aspects.

5.1.2 The SoSAD Social Simulation

The social simulation component takes data as input and produces additional data as output. From the input data, it parameterizes the agent-based model by means of model generators. These generators pre-process and aggregate data from several sources before it can be used in the model.

The most important generator populates the simulation with agents. It uses actual or synthetic demographic data to construct an agent population. In the case of actual data, a municipality's register of residents is directly fed into the population generator. From this data, an agent with a corresponding age is created for each resident. If several persons live together, their respective agents become connected in the same household. These households are grouped by statistical districts to abstract from addresses and make individual persons harder (or impossible) to identify. To guarantee anonymity, registry data can also be replaced with a synthetic population generated from census data. In either case, the population generator uses as little data as possible to construct an accurate digital twin representation of a municipality's inhabitants for social simulation.

Furthermore, there are several generators for a municipality's infrastructure that agents in the simulation can frequent. For instance, children attend schools which are generated from data about the numbers of pupils and classes per grade for each school. This is combined with the population data to assign agents with an appropriate age to school classes. From these assignments, a generator creates schools and classes as locations in the simulation model and populates these with the respective agents.

In order to run the simulation, AScore also stores and provides a library of scenarios. In these, combinations of counter-pandemic intervention measures are specified which can be compared using simulation. The SoSAD component takes the chosen scenarios from the management cockpit, creates the respective parameterized simulation model using its generators and then runs the simulation to produce the required results. Those results are also defined by the scenarios in terms of output variables that will be compared. Thus, simulations in AScore can essentially be run in the form of hypothesis-driven studies that provide comparative answers to questions about the impacts of intervention measures (Lorig et al. 2017).

The results of those simulation studies are finally returned to the data storage. They can come in the same form as real-world observations about the actual situation. This enables the analytics engine and the management cockpit to utilize the same tools and visualizations for comparing hypothetical what-if scenarios as for displaying the current what-is situation. The goal of this approach is to make simulation as an advanced decision-support technique accessible to non-specialists in crisis management.

5.1.3 The Measures-Impact Repository

One of the goals in AScore is to establish structures that allow for analyzing the quality of intervention measures taken during a pandemic. In order to do so, a Measures-Impact Repository is being developed in the project. That repository is meant to store information about which measures had been taken in the past and what effects could be observed with respect to the various dimensions of the Pandemic Pressure Score. This is a complex task, since it is almost impossible to identify, capture, and store all information that constitute the current status in all its complexity, let alone the factors that have an influence on the state and are not simply defined in an official, pandemic-related measure. E.g., factors like weather, mobility or the influence of media can often have a massive impact on the development of a pandemic disease.

Yet, even without the complete picture relevant information can be gathered. On the one hand, this includes all information about the official measures to contain COVID 19. They need to be translated to a common representation allowing for a comparison between different measures (see Section 5.3.2). On the other hand, it contains at least all status information (see Section 5.1.1) provided through the Management Cockpit.

Since data are often corrected over time (e.g., due to delayed reporting of cases of illness), it is misleading to use the corrected figures retrospectively. If one wants to reconstruct which information was available on a certain day within a management cockpit to support decision-making, a much more complex procedure is necessary to enable such reconstructions–also with regard to the resources available for data storage. Consequently, histories of data series are captured in AScore in the exact form that they had at the time of decision about intervention measures, e.g., for the figures on incidences and deaths collected by RKI.

Moreover, the Measures-Impact Repository connects data from different sources to allow for a more complete picture. For instance, the measures themselves can be extracted from official regulations and decrees as publishes by municipalities and states. These are then linked to directories of registered businesses in order to establish how many companies in which business areas or trades are affected by these measures (e.g., in a partial lockdown). Similar connections include directories of schools, sports facilities and other locations with registers of residents to analyze impacts of measures on families, requirements for emergency childcare, as well as physical and mental well-being. Linking data in this way allows for capturing the particular impacts of intervention measures not only on viral spread but also on public and private life in general.

5.2 AScore Infrastructure and Components

One of the aims of AScore is to provide a prototypical infrastructure that illustrates the potentials of the approach and that allows for being used as a basis for further developments by project partners and other stakeholders. In order to realize this, it is possible to build upon several existing DFKI components (cf. Memmel et al. 2017, Sabty et. al 2013) that are being enhanced and adapted for the needs of AScore. This, e.g., concerns data integration, data storage, and interfaces for data provision, simulation model components and generators, as well as components for data visualization. Yet, some tasks require a considerable amount of refactoring or even the development of completely new components. Fig. 1 provides a coarse overview of the AScore infrastructure and main components that will now shortly be introduced.

5.2.1 Adapters & Preprocessing

In AScore, both (quasi)-static and dynamic data are processed. Quasi-static data sets (e.g., municipal registration data, POIs, or data from OSM) change only after comparatively long time intervals and therefore need to be updated less often than dynamic data. The latter are transmitted via service interfaces. In any case, appropriate adapters and connectors for (semi)automatic integration and normalization of both quasi-static and dynamic need to be available.

Furthermore, different preprocessing steps are required that allow for an appropriate access to data (e.g., for the AI analytics Engine and for interactive visualizations), an efficient storage, or the integration into the measures-impact repository.

5.2.2 Data Storage

The data repository is a central component in AScore, combining elements of classic spatial data infrastructures with other modules, e.g., that allow for an efficient storage and management of textual data. The data storage will contain all input data relevant for the tasks described in Section 5.1.1, 5.1.2, and 5.1.3. The data storage will also provide refined data and intermediate results, as well as the metadata, especially also with suitable historization concepts to be able to observe temporal changes.

5.2.3 AScore API

In order to allow accessing the data in the data storage, the communication between different components, and especially the access for the AScore Management Cockpit and 3rd party applications from other stakeholders and project partners[4], an API will be developed.

[4] In the project, two sample applications are covered here: EpideMSE by Fraunhofer ITWM and the Coronavirus Exposure Tracker by CID GmbH.

5.2.4 AScore Analytics Engine

This component holds all methods to analyze data within AScore. This includes aspects such as the calculation of a Pandemic Pressure Score and algorithms to find patterns in the measures-impact repository. The engine makes use of various methods, described, e.g., in (Wang et. al 2018) and (Janowicz et. al. 2020).

5.2.5 SoSAD social simulation

This component encapsulates the agent-based social simulation as described above. The simulation interacts with the AScore API using its input and output data generators. Real-world data is retrieved from, and simulation results are stored in the Data Storage to make the simulation accessible to the AScore Management Cockpit as well as any 3rd party applications. Moreover, this makes simulation data also available to the AScore Analytics Engine for comparing scenarios according to their Pandemic Pressure Scores and further analyzes.

5.2.6 AScore Management Cockpit

The Management Cockpit denotes the visual user interface for crisis managers. It comprises a dashboard for what-is-analyzes to increase awareness of the current pandemic situation as well as scenarios of available intervention measures to compare what-if-analyzes for decision-support. Since there are different perspectives from different fields of expertise present in a crisis management staff, the dashboard and the analyzes can be customized to individual information needs. However, being based on the same Data Storage and analysis tools, the AScore Management Cockpit furthers communication and agreement between staff members.

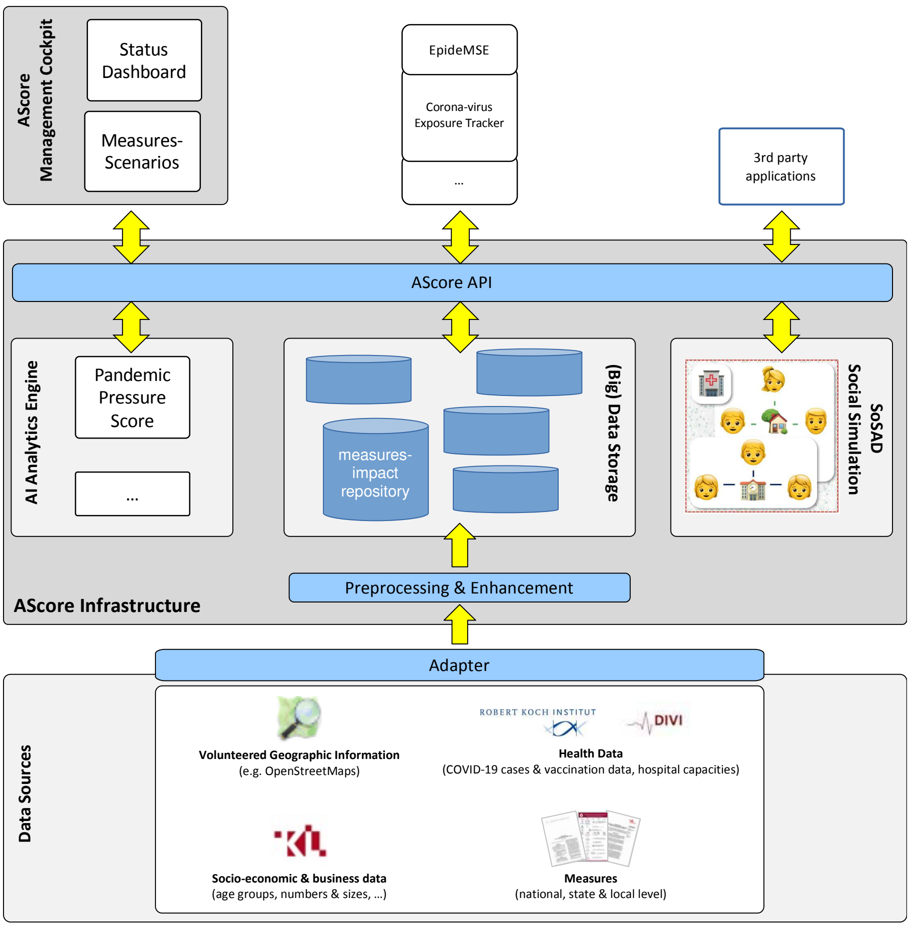

Fig. 1: A coarse overview of the AScore infrastructure and main components.

5.3 Realizing a Management Cockpit – First steps

As a basis for discussing requirements and needs with stakeholders from crisis management and also within the AScore project team, first steps to realize the envisioned management cockpit were already realized. Figure 2 provides an overview of some of the available information as of May, 2021.

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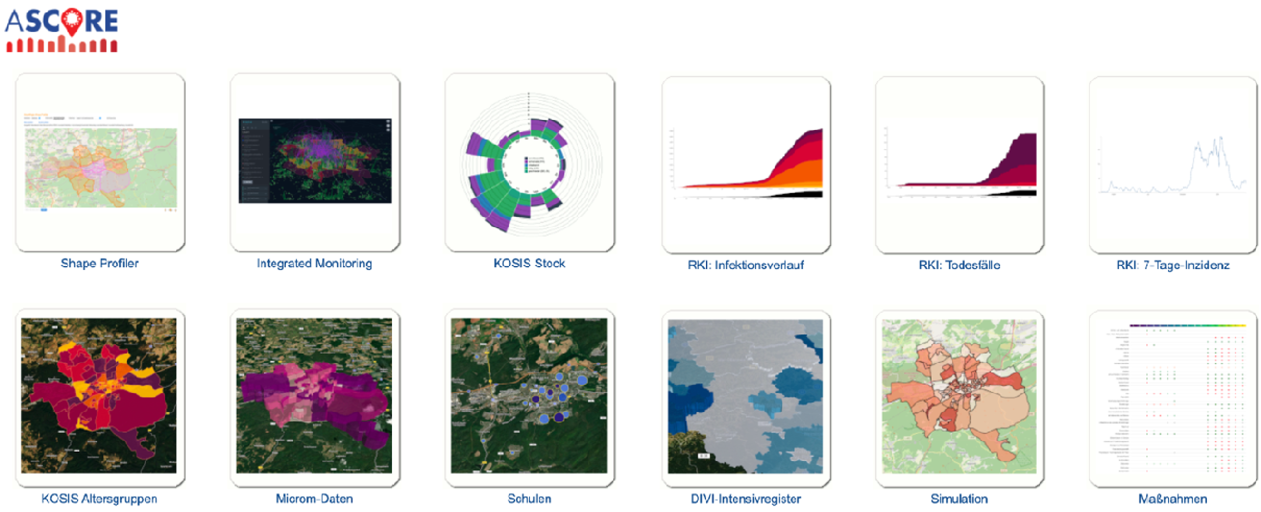

Fig. 2: Overview of information items available in the early development stage of the AScore management cockpit.

5.3.1 Map-based Status Information

Map-based visualisations are often particularly suitable for enabling assessments of different statuses or developments at the regional level or in comparison to other regions. In the context considered here, this applies to many forms of information, some of which are shown in Fig. 3:

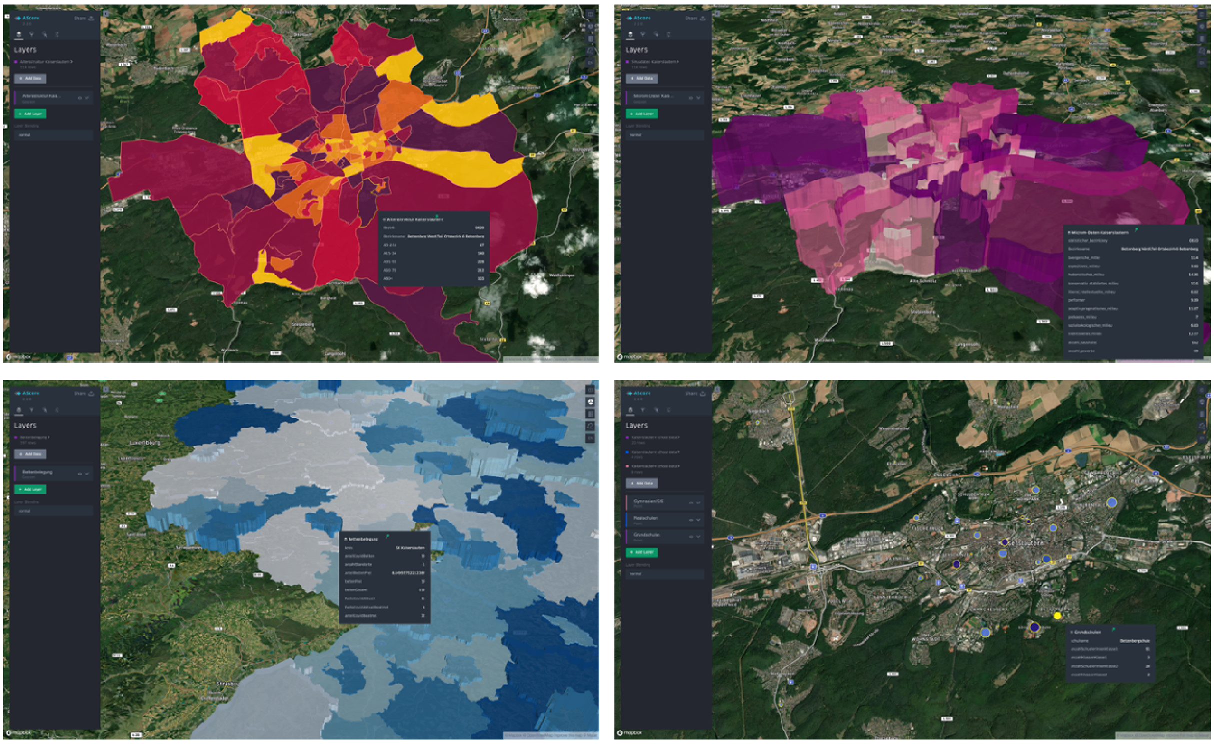

Fig. 3: Interactive, map-based visualization[5] of (a) age groups, (b) business activities, (c) ICU capacities, and (d) schools (clockwise).

(a) The distribution of age groups (and social milieus) can be used, for example, for specifically addressing certain population groups or to put a focus on social groups that may be particularly vulnerable. The age groups shown here are derived from civil registration data that the city of Kaiserslautern provided in a standardized format (KOSIS).

(b) Information on various business activities (in this case provided in microm data about Kaiserslautern) allows to draw conclusions, for example, about the effects of pandemic containment measures.

[5] AScore builds upon an integrated monitoring infrastructure developed within DFKI's SmartCity Living Lab. It is a generic, module-based web application built upon a distributed data storage and offers several means for visualizations. The interactive visualizations shown in Fig. 3 were realized using the open-source software kepler.gl.

(c) Register information about the availablity of hospital capacities allows to estimate the development of the severeness of the pandemic and to react as soon as posible if capacities become scarce. The information depicted here derives from the DIVI Intensive Care Register, a real-time data collection and analysis environment for intensive care bed capacities and aggregated case numbers for Germany.

(d) The representation of schools with information on the age groups taught there allows, for example, adequate mobility planning.

5.3.2 Visualization of Intervention Measures

In the course of the pandemic, various authorities (federal, state, municipal) adopted a wide range of measures to contain COVID 19. These affect a wide range of social aspects in a variety of ways. For example, different rules apply to large events than to trade or schools. In many cases, the rules within individual sectors are also very differentiated and often apply depending on local incidence figures. In order to enable an overview of measures that are currently valid and those that were valid in the past, an interactive visualisation of such measures was developed in AScore (see Fig. 4). On the y-axis, different areas affected by intervention measures are displayed, on the x-axis the measures (grouped by regulation or as a timeline) are shown. The colors indicate how much the respective areas have been affected by the measure: “red” indicates that they have to be completely closed, “yellow” means a medium impact, and “green” indicates that the area was not affected. This tool requires a comparable representation of areas across different measures and has been realized, among other things, based on publicly available readout aids.

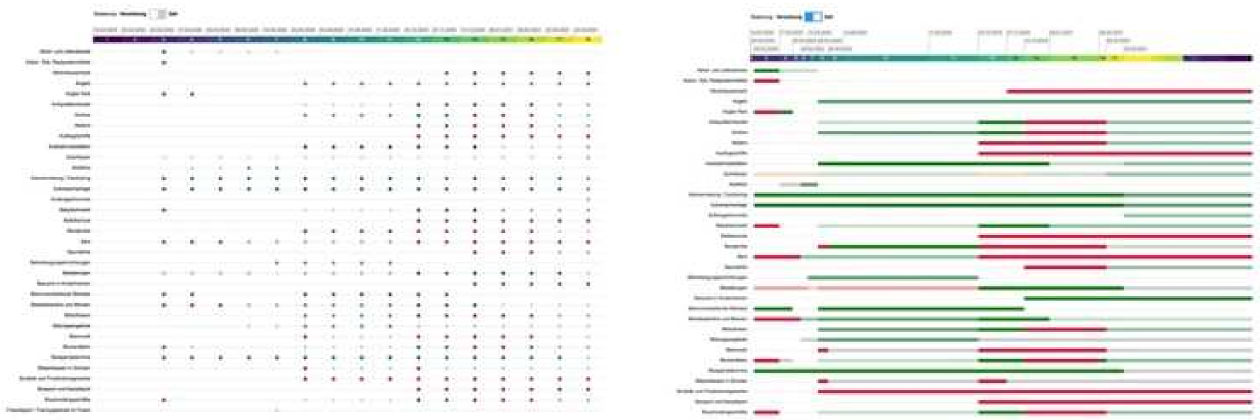

Fig. 4: Interactive visualization of pandemic containment measures and affected fields of society in two different modes of presentation: and grouped by regulation (left) and as a timeline (right).

6 SAMPLE USE CASES: SITUATION EVALUATION AND DECISION SUPPORT

Over the course of a pandemic, crisis staffs meet regularly to evaluate the overall situation and to decide whether action needs to be taken. Consequently, use cases of the AScore project can be grouped into two main areas: Those that cover general information interests and those that directly support specific decisions. From general information, crisis staffs can derive the need for action whereas decision support only comes into play as a second step when deciding between several alternatives.

For evaluating the current pandemic situation, crisis staffs require an overview in the form of situation reports. These need to be up-to-date and cover the various areas of expertise of different staff members. To meet these demands, users can customize their view of the Management Cockpit with those detailed analysis components they deem important while still keeping an overview of other areas through the Pandemic Pressure Score. For instance, the local health authority has to report on registered infections and work together with hospital managers to reserve capacity for expected severe cases that will need intensive care. Having a localized and customized dashboard available helps these users communicate with each other. In particular, they can observe the current situation as well as similar ones from the past (if available) to make sure to call for action at the appropriate time. The Pressure Score is their main asset for doing so: If the public health situation deteriorates, pressure on the healthcare system will increase. The AScore management cockpit uses that score to help detect these developments and interplays through indicators, what-is-analyzes and visualization such that intervention measures can be taken in a timely manner.

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However, the Pressure Score does not only help determining when to intervene to contain the pandemic. Since intervention measures exert pressure on private and public life, culture and economy themselves, the score is equally important to detect potential and find ways for alleviating that pressure. This leads to specific decision-making tasks for a crisis management staff. Both putting measures in place as well as lifting them requires decisions about which specific interventions are appropriate and how they can be designed to have the desired impact while avoiding undesired side-effects. To that end, decision-makers use what-if-analyzes to compare hypothetical scenarios of situations that have not yet been observed in reality.

In this role, an early version of AScore has already been utilized for supporting decisions by crisis staff members and municipal councils. Examples cover decisions about when and whether to open or close schools (and how to organize public transport accordingly) as well as whether to open public swimming pools. In that context, simulation scenarios were run in which schools were closed completely, opened as normal, or opened for only half the students at a time with regular rotation of the cohorts. These scenarios were analyzed not only according to the number of expected infections in school but also according to the possible further spread of the disease (i.e., with respect to the role of schools as a multiplier of the general infection dynamics). It turned out that the rotational strategy increases infections across the population only slightly over completely closed schools–while at the same time drastically decreasing the organizational burden upon families. These results were visualized by means of time series plots, scenario heat maps, and geographical analyzes of locations for potential outbreaks of COVID-19. Up to the time of writing, the rotational strategy has been in place for several months and no major outbreaks have been reported in the partner cities that derive from infections in school.

7 SUMMARY AND FUTURE WORK

To summarize, the AScore project aims at developing an information system for crisis managers in the context of pandemics. Its core contribution and innovation is in bringing together smart cities technology for data retrieval, analysis, and visualization with agent-based social simulation. While the former supports what-is-analyzes of the current pandemic situation to identify the need for action, the latter allows for comparing what-if-analyzes of hypothetical scenarios to decide upon which specific action to take. This paper has outlined the overall concept of AScore, introduced its architecture and components, and briefly sketched its uses for practical decision-making. AScore, however, is still being developed and there is still work to do. This implies several challenges that need to be overcome. Firstly, additional indicators for the Pandemic Pressure Score must be specified and implemented. This is challenging because data private life and public institutions is hard to retrieve due to privacy or security reasons. Secondly, presenting analysis and simulation results to crisis staff members in a meaningful way is a non-trivial task. Future work will thus cover customizability of the dashboard and scenario components. Finally, AScore is meant to provide open interfaces for 3rd party analysis tools. These will be developed and tested with sample tools of the project partners.

Beyond the AScore project, the combination of agent-based social simulation and smart city technologies is being further developed for many other urban application areas, such as urban planning or climate protection.

8 REFERENCES

Luis Alonso, Yan Ryan Zhang, Arnaud Grignard, Ariel Noyman, Yasushi Sakai, Markus ElKatsha, Ronan Doorley, Kent Larson. Cityscope: a data-driven interactive simulation tool for urban design. Use case volpe. In International conference on complex systems. pages 253-261. Springer, Cham, 2018.

Martin Bicher, Claire Rippinger, Dominik Brunmeir, Christoph Urach, Niki Popper. Agent-Based COVID-19 Simulation Model. Model Specification. dwh GmbH, Vienna, 2020.

Michael Bortz, Michael Burger, Jochen Fiedler, Simone Gramsch, Neele Leithäuser, Jan Mohring. EPIDEMSE. Epidemiologie – Modellierung, Simulation und Entscheidungsunterstützung für lokale Entscheidungsträger. Whitepaper. Fraunhofer-Institut für Techno- und Wirtschaftsmathematik ITWM. Kaiserslautern, 2020.

Christiane Dings, Katharina Götz, Katharina Och, Iryna Sihinevich, Dominik Selzer, Quirin Werthner, Lukas Kovar, Fatima Marok, Christina Schräpel, Laura Fuhr, Denise Türk, Hannah Britz, Sigrun Smola, Thomas Volk, Sascha Kreuer, Jürgen Rissland, Thorsten Lehr. COVID-19 Simulator. Modelling for the German federal states. https://covid-simulator.com/en/. Clinical Pharmacy, Saarland University, 2021 (retrieved 02 Jun, 2021).

Dong, Yuanyuan, X. I. Mo, Yabin Hu, Xin Qi, Fang Jiang, Zhongyi Jiang, and Shilu Tong. Epidemiological characteristics of 2143 pediatric patients with 2019 coronavirus disease in China. Pediatrics 145:6, 2020.

Matthias an der Heiden, Udo Buchholz. Modellierung von Beispielszenarien der SARS-CoV-2-Epidemie 2020 in Deutschland. Robert Koch Institut. Berlin, 2020.

Chung-Yuan Huang, Chuen-Tsai Sun, Ji-Lung Hsieh, Yi-Ming Arthur Chen, Holin Lin. A Novel Small-World Model: Using Social Mirror Identities for Epidemic Simulations. SIMULATION 81:10 pages 671–99, 2005.

Krzysztof Janowicz, Song Gao, Grant Donald McKenzie, Yingjie Hu and Budhendra Bhaduri. GeoAI: spatially explicit artificial intelligence techniques for geographic knowledge discovery and beyond. International Journal of Geographical Information Science, 34:4, pages 625-636, 2020.

Fabian Lorig, Daniel S. Lebherz, Jan Ole Berndt, Ingo J. Timm. Hypothesis-Driven Experiment Design in Computer Simulation Studies. In: Chan, W. K. V.; D'Ambrogio, A.; Zacharewicz, G.; Mustafee, N.; Wainer, G.; Page, E. (Eds.): Proceedings of the 2017 Winter Simulation Conference (WSC 2017). pages 1360-1371. IEEE, 2017.

Fabian Lorig, Emil Johansson, Paul Davidsson. Agent-Based Social Simulation of the Covid-19 Pandemic: A Systematic Review. Journal of Artificial Societies and Social Simulation 24 (3) 5, 2021.

Martin Memmel, Andreas Abecker, Sebastian Bretthauer, Heinz Kirchmann, Roman Korf, Markus May and Richard Wacker. Smart Regio - Employing Spatial Data to Provide Decision Support for SMEs and City Administrations. In Manfred Schrenk, Vasily V. Popovich, Peter Zeile, Pietro Elisei and Clemens Beyer, editors, Proceedings of REAL CORP 2017, pages 507-519, 2017.

Caroline Sabty, Martin Memmel and Slim Abdennadher. GeoEvents - An Interactive Tool to Analyze and Visualize Spatial Information from the Social Web. In Proceedings of the ASE/IEEE International Conference on Social Computing, pages 803-808, 2013.

Shaohua Wang, Xianxiong Liu, Haiyin Wang and Qingwu Hu. A Case Study on Spatio-Temporal Data Mining of Urban Social Management Events Based on Ontology Semantic Analysis. Sustainability 10(6):2084, 2018.

Yixian Zheng, Wenchao Wu, Yuanzhe Chen, Huamin Qu and Lionel M. Ni. Visual analytics in urban computing: An overview. IEEE Transactions on Big Data, 2(3), pages 276–296, 2016.

Fei Zhou, Ting Yu, Ronghui Du, Guohui Fan, Ying Liu, Zhibo Liu, Jie Xiang, Yeming Wang, Bin Song, Xiaoying Gu, Lulu Guan, Yuan Wei, Hui Li, Xudong Wu, Jiuyang Xu, Shengjin Tu, Yi Zhang, Hua Chen, Bin Cao. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. The lancet 395.10229. pages 1054-1062, 2020.

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