From Research to Crisis Management: Multiagent Simulation for Local Governments

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Abstract. During the COVID-19 pandemic, a rise of (agent-based) simulation models for predicting future developments and assessing intervention scenarios has been observed. At the same time, dashboarding has become a popular way to aggregate and visualise large quantities of data. The *AScore Pandemic Management Cockpit* brings together multiagent-based simulation (MABS) and analysis functionalities for crisis managers. It combines the presentation of data and forecasting on the effects of containment measures in a modular, reusable architecture that streamlines the process of use for these non-researcher users. In this paper, the most successful features and concepts for the simplification of simulation usage are presented: definition of scenarios, limitation of parameters, and integrated result visualisation, all bundled in a web-based service to offer a low-barrier entry to the usage of MABS in decision-making processes.

Keywords: Multiagent-based simulation · COVID-19 pandemic · Crisis management · Decision-making cockpit

1 Introduction

With the beginning of the COVID-19 pandemic, the need for easily available information for the population and governments increased. Thus, a large number of pandemic dashboards was proposed by companies and research groups across the globe. Infection numbers, hospital capacities, vaccination rates and other statistics were displayed in graphs and coloured maps. However, the scope of data processing was usually limited to simple visual presentation and basic aggregation without interpretation, requiring additional expert knowledge to assess the presented results accurately [1].

Furthermore, forecasts on the course of the pandemic were required in addition to the current data and facts presented in those dashboards, especially for making political decisions. Different simulation models were presented, including a number of agent-based models (ABMs) [2]. ABMs compete against established equation-based models. As a result, the usage of mutliagent-based simulation (MABS) for policy decisions was not particularly widespread [3]. Easy access

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to information and its interpretation, as well as forecasts, are the three main features needed by governments to manage the pandemic. This work presents the simulation-based cockpit *AScore*, which combines these spheres of dashboarding and multiagent-based simulation to support policy-makers in local government with the assessment of the pandemic situation in their region and possible outcomes of different intervention decisions. Section 2 outlines the main purpose and goals of AScore, Sect. 3 demonstrates its application and in Sect. 4 we conclude on the lessons learned from bringing agent-based simulation into practice.

2 Purpose of the AScore Pandemic Management Cockpit

The simulation-based cockpit AScore was developed in cooperation with crisis managers in Germany during the COVID-19 pandemic. Its main purpose is to help local governments manage the pandemic with a holistic approach [4]. This includes the presentation of up-to-date data and information that is aggregated and evaluated to allow for assessing the overall situation in a chosen region. However, AScore aims not only at providing an overview of the current situation, but also at the possibility to evaluate future developments using an agent-based simulation approach. For that, an ABM based on population data is used to produce understandable and explainable results in real-world scale of a German city – such that each inhabitant is represented by an agent in the simulation. Accessibility of the underlying simulation used for predictions when examining possible impacts of policy decisions is a major factor in determining whether people are willing to take advantage of MABS or not [5,6]. By streamlining the process of running meaningful simulations and viewing their results, users experience reduced entry barriers to the use of AScore in their workflows.

AScore supports these objectives with modular architecture that can be used for different models, even outside of the pandemic context. Such a modular architecture includes visualisation of results which addresses an issue often encountered by developers of ABMs: easily understandable visualisation and presentation of simulation results is often time consuming [7]. As such, this kind of architecture, which emphasises reusability and interchangeability of components, is an important approach to addressing the high cost and effort associated with the presentation of different simulations to stakeholders.

3 From Research to Practice: Demonstration of AScore

In this section, we present the architecture of the simulation-based cockpit and how its design contributed towards the overall quality and usefulness of the system in its practical application during crisis management counselling.

3.1 AScore Architecture

Figure 1 displays the general architecture of the AScore dashboard. The ecosystem consists of four major components: the actual management cockpit, which

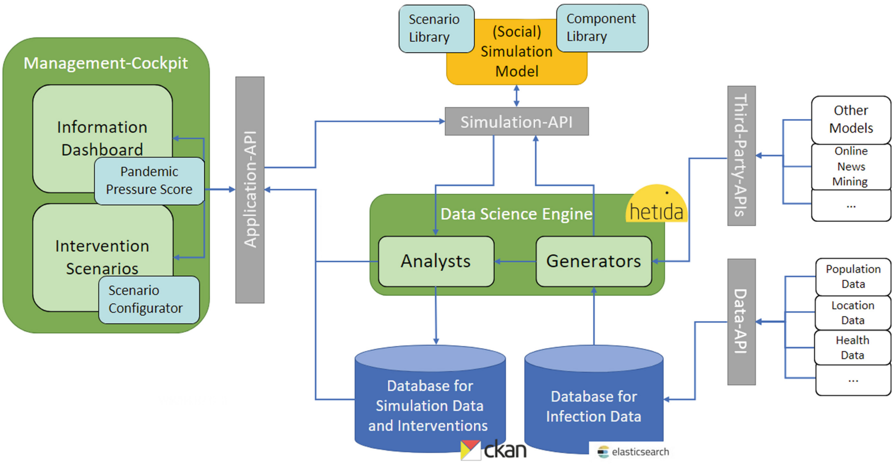

Fig. 1. AScore architecture diagram

is the frontend presented to users, and the three underlying backend components. There is the agent-based simulation, along with metadata on its scenarios and components, which is connected to the system by an API. This means the simulation is a modular component which can be switched with another model, increasing the reusability of this architecture. A CKAN [8] database and an Elasticsearch [9] instance are used for the management of unstructured, file-based data, both for the dashboard visualisations and for simulation inputs, as well as the results of a simulation which can be viewed in the dashboard. To process this needed input and also the output data, a data science engine, such as the open source framework *hetida designer* [10] serves as a connecting component. Different APIs serve as connectors between the four components, ensuring modularity.

3.2 Agent-Based Simulation Scenarios

Based on active use for decision making, simulations are usually conducted with respect to specific issues. Typically, these are if-then questions that examine the impact of specific decisions such as the mandated home office. To facilitate such targeted simulations, scenarios of particular interest were identified in collaboration with members of rapid response groups, local governments, and other potential users. The following were deemed of particular importance: *Impact of home office*, *Impact of alternate instruction and different testing strategies at schools*, and *Impact of lockdown*. Figure 2 shows the overview of the different scenarios under which users can find previous simulation results that, when requested for analysis, are loaded from the CKAN database. In addition, it is also possible for users to freely design own scenarios using more than twenty parameters. However, to lower the complexity of the model there are also fixed

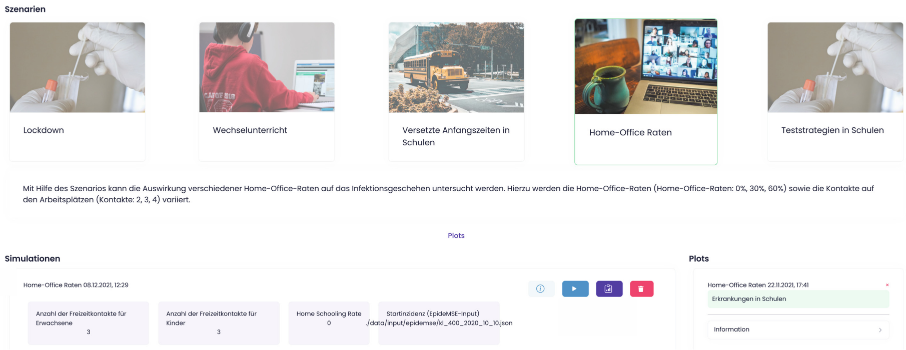

Fig. 2. Selection of scenarios and available simulation data

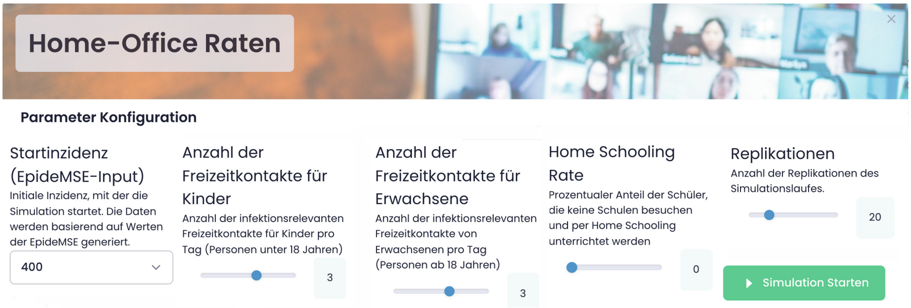

Fig. 3. Configuration interface of the *home office*-scenario

parameters, which are usually verified by experts, scientific data, data drawn from other sources (i.e. population data) or parameters not needed for the specific scenario studied. Figure 3 shows the interface for the configuration of the home office scenario in this case – while users may want to adjust the contact behaviour of the population, constants are not displayed at all, reducing the complexity of the configuration process.

3.3 Simulation Result Visualisation

Once a simulation has is done, the output data is processed and visualised using custom workflows in hetida, allowing for the selection of relevant data to be displayed. Figure 4 shows a selection of plots that compare the infection dynamics for three different home office rates and different contact behaviours among adults. The graphs display both case numbers in the general population and in schools, allowing the examination of different population groups or metrics besides simple case numbers. Apart from infection dynamics, there are a number of other output data that can be used to create charts such as hospitalisation, mortality and more. In addition, users can view the results of the scenarios with their respective progress in the simulation player in Fig. 5. This player visualises

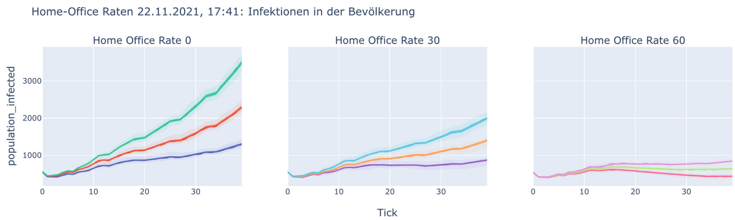

Fig. 4. Visualisation of results for the *home office*-scenario

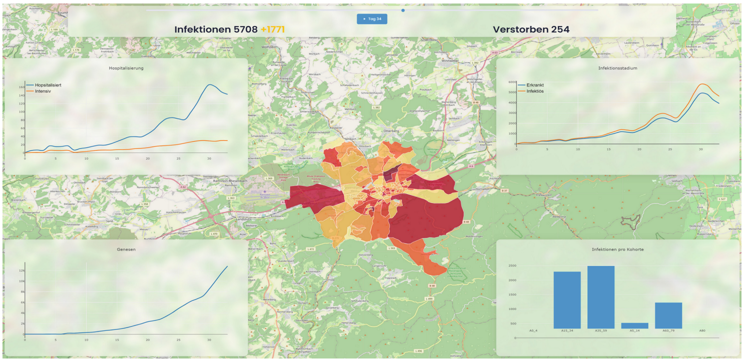

Fig. 5. Simulation player for the visualisation of individual experiment setups

the results of a parameter combination (averaged across different random seeds) step by step, increasing the transparency of the simulation results and making it more accessible and explainable to users. This model, based on the city of Kaiserslautern in Germany, maps locations and their 100’000 inhabitants to the statistical districts of the city as provided in the population data. This allows the model to map the case numbers to their specific districts and cohorts allowing an identification of possible hot-spots. This gives the user insights that cannot be obtained from a static set of plots.

4 Lessons Learned

Due to the unique combination of data presentation, evaluation of results and simulation-based forecasting, the AScore Cockpit contributed to pandemic management. Over the course of the pandemic, the authors actively participated in municipal crisis management and gave counsel on different topics, such as schooling strategies, opening of public swimming pools or extended holidays at the start of the new year. An important aspect of this success is the flexibility of such a system, allowing quick adaptation to unexpected events, such as new variants [11], recent policy changes and interventions. Especially with the emergence of the Omicron variant, the demand for forecasts was high. The forecasts by AScore were able to support decision makers in assessing this. With uncertainty and low availability of data, multiagent simulation is well suited to adapt to new information by retaining its high explainability, an advantage that sets it apart from purely mathematical or data-driven approaches.

However, once the COVID-19 pandemic wanes from public attention, simulation models and information dashboards for the visualisation of current pandemic data will likely fade from acute interest as well. Thus, the reusability of different technologies is an important topic not just for disease scenarios, but other, especially regarding civil security contexts. Like the visualisation and analysis of the data, the scenarios generated with the support of experts further help to simplify the use of MABS and maintain its explainability. While not all simulation contexts and models may benefit from the use of a dashboard for the visualisation of data, there is still an argument to be made in favour of using a generic architecture and therefore decrease the entry barriers to MABS in practical use by streamlining the process as much as possible. The AScore technology stack is also promising due to its modular nature, permitting the replacement of components without forcing developers to start over from scratch. The successful reuse of components and inclusion of another simulation model has already been tested during the development of another project for the support of crisis resilience in critical logistic supply lines. A continued usage for components of this architecture, without data aggregation and visualisation components, is planned in the context of future projects involving MABS.

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