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TOWARD HYBRID SIMULATIONS FOR CARE DEMAND FORECASTING

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ABSTRACT

Demographic change leads to an increasing demand of health care services. To provide the required services at the right locations, methods for forecasting future demands are needed. The goal of this research is to combine two different simulation techniques to forecast future care service demands. On the one hand, forecasts of demographic change are required. On the other hand, a plausible forecast must account for individual decisions for specific types of care. Thus, the paper outlines an approach to combine statistical micro-simulation of demographic change with agent-based social simulation of individual interactions.

1 FORECASTING CARE DEMAND

Demographic change has become a prevalent phenomenon in industrialized countries. Increased life expectancies increase the demand of health care services. In addition, urbanization and a high mobility of young professionals lead to a fragmentation of families over large geographic distances. This aggravates the demand for professional care in rural areas where care infrastructure is sparse and in border regions where different organizational structures of care services meet (Münnich, Kühn, and Simoes 2017). To satisfy that demand, it is necessary to provide the required facilities and services at the right locations. Because establishing that infrastructure takes time, methods for forecasting future demands are needed.

This research is based on computer simulation as an analysis method (Timm and Lorig 2015). Its goal is to combine two different simulation techniques to forecast care demand in a hybrid system. This requires forecasts of demographic change. Population structures must be projected into the future to derive where care is needed by whom. However, it is difficult to derive actual demands directly from population developments. The demand for professional services depends on the availability of informal care by family members and on individual decisions to make use of it. Hence, the demand for specific types of care is an emergent effect of this decision-making. To take this into account for a plausible forecast, the following section outlines an approach to combine statistical micro-simulation of demographic change with agent-based social simulation for deriving care demands from individual behaviors and interactions.

2 COMBINING STATISTICAL MICRO-SIMULATION AND AGENT-BASED SIMULATION

In the presented approach, the two components of statistical micro-simulation and agent-based social simulation cover different aspects of the forecasting procedure. Consequently, they aim at different goals and have different requirements to effectively contribute to care demand forecasts in a hybrid simulation.

The first component is statistical micro-simulation (Rahman and Harding 2016). It projects a population into the future in order to simulate demographic change. For a realistic forecast, this simulation integrates various data sets describing the current population, the amount of care needed, and probable future changes. The population comprises persons with attributes like gender, age, and family status. For Germany, *census data* provides distributions of these attributes within grid cells of 100×100 meters. From these, a synthetic population is created and individual persons are mapped to geographic addresses using data from the

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OpenStreetMap project. Then, *health care statistics* are applied to identify individuals who are in need of care. These are candidates for utilizing professional care services. Finally, *statistics of demographic developments* (e.g., mobility, fertility, mortality) project the population into the future. This data combination facilitates statistical micro-simulations to forecast care service consumers and their geographical locations.

The second component is agent-based social simulation (Davidsson 2002). It covers individual behavior and preferences in the decision-making for specific types of care services. In contrast to the data-driven statistical simulation, this component is largely theory-driven. It instantiates individual persons from the synthetic population as software agents. These agents choose among several alternatives of care service utilization. *Agent technology* provides cognitive agent architectures and communication methods for that decision-making. Using agent communication, *social mechanisms* model the influence of social networks (e.g., relatives and friends) on an agent's decisions. The individual behavior of agents is modeled using stereotypical *social actor types*. Moreover, *decision theory* maps these actor types to subjective expected utility values which an agent attempts to maximize to select care services. By combining several actor types to different extents within each agent, it is possible to represent individual agent preferences and to model highly diverse populations in a social simulation.

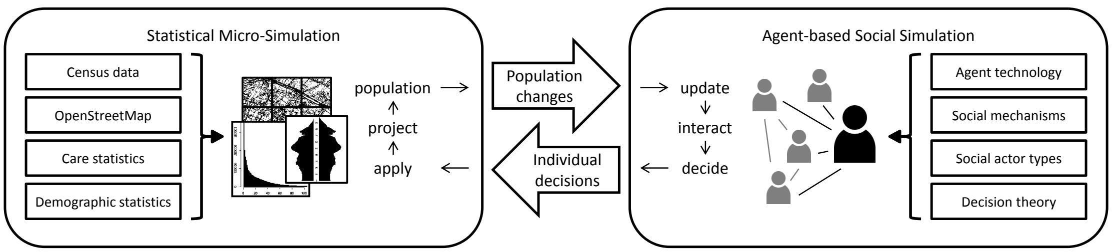

Figure 1: Interplay between statistical micro-simulation and agent-based social simulation

Figure 1 shows the simulation components and their interaction. Combining statistical micro-simulations and agent-based social simulations includes both demographic developments as well as individual interactions into care demand forecasting. The hybrid approach consists of a back-and-forth procedure of these simulations. First, an initial synthetic geo-located population with all relevant attributes is generated from statistical data sources. Then, a matching agent population is created. The agents representing individuals in need of care determine which type of care they prefer. They interact with relatives and friends in order to decide what services to utilize. From those decisions emerges the overall demand for particular care services in specific geographical areas. They are fed back to the statistical micro-simulation to affect changes in the population structure (e.g., persons moving to stationary care or marking relatives as care-givers). Together with statistics of demographic change, this projects the population into the future (e.g., by one year). The updated population is then sent to the agent-based simulation, again, which generates new decisions for all individuals whose health care requirement status has changed. Continuing this loop allows for taking account of both macro-social developments and micro-social interactions for care demand forecasting.

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