AMiCUS: An Agent-based Model for CommUnity driven Supply in rural areas

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Abstract

As a result of demographic change and growing urbanization, remaining populations from rural areas even in developed countries are facing new challenges. For an increasing number of elderly people there is only a steadily declining number of stationary stores for everyday goods. At the same time, however, new possibilities for support are emerging as a result of the growing digitalisation. Without adapting the infrastructures, for example, community-based digital services can support the provision of people's supply: via a digital service platform, private individuals help each other in everyday errands. The quality and usefulness of community-based services are generally dependent on a number of active users and, in that case in particular, on their movements in space and time. This number of users again strongly correlates with the quality and utility of such a service. The authors present an agent-based model (ABM) to investigate this interaction. In order to be able to estimate the opportunities and challenges of such services, the model will be carried out in a simulation with data and calculations from geographic information systems (GIS) for the region Ostwestfalen-Lippe, Germany.

Keywords: Agent-Based Modelling (ABM), Geographic Information Systems (GIS), community driven services

1 Introduction and motivation

Urbanization is one of the most significant population trends of the last 50 years. Remaining populations from rural areas, mainly elderly due to demographic change, face challenges such as the low supply of services that support daily needs, e.g. food and medication purchases. The development of services that meet the needs of those citizens is crucial (Kinsella 2001).

The Europe 2020 Strategy (European Commision 2010) affirms, that regions should develop smart and sustainable social economics. According to (Hess et al. 2015) a smart region provides its functions with a focus on services instead of infrastructure. Meanwhile, innovations and research in smart services were focused on dense metropolitan areas with a recent shift towards rural areas (Ferretti & D'Angelo 2016).

(Koch et al. 2016) developed a strategy for providing smart package delivery in rural areas which focuses on community-driven services. Those community-based approaches suffer from the chicken-egg dilemma, meaning the performance of the system is directly related to the number of users and vice versa. Therefore, a useful service needs a critical number of active users to be functional.

From the authors point of view user acceptance for such a service is especially location dependent. However, an analysis of the relevant spatial-geographic, socio-spatial and infrastructural relationships is not trivial. In addition to a classical geographic information system (GIS) model, network analysis and, in particular, dynamic interactions need to be examined. The authors therefore suggest to link the technological possibilities of the GIS-based analysis with the dynamic capabilities of a multi-agent simulator.

Agent-based simulations are established methods to analyze complex socio-technical systems within spatial environments (Heppenstall et al. 2016). For example they can be used to evaluate demand-responsive transport systems (Čertický et al. 2014). Although agent-based models are especially used for the recognition of social-scientific problems, there are no models that deal with the behaviour of users in digital community-based services.

In this paper, the authors describe an agent-based model (ABM) and simulation environment as a basis for future investigations of potential strength and weaknesses of a community-driven supply service.

2 AMiCUS

The community-driven service AMiCUS provides a platform for people to help each other to supply with everyday goods in rural areas. The basic idea is that there are still people who are moving, e.g. commuting within or between rural and urban areas. These people can act as suppliers for orders made by consumers who remain in rural areas due to mobility-related obstacles, e.g. high mobility cost or being mobility-impaired. A potential supplier might query those orders to evaluate which could be fetched from a shop and delivered to the consumer

without much detour. The consumer has to pay the order along with some additional fee for the supplier.

On the one hand it seems obvious that there are advantages of using a community-driven approach in solving challenges that appear due to demographic change and urbanization. Shared economy and shared mobility are notable trends which could be transformed and modified to work in rural areas. The described service could achieve a decent supply situation without establishing new infrastructure (e.g. public transportation).

On the other hand, establishing such a community-driven service is difficult. Besides having a sustainable business model, one main challenge for success is user acceptance. Therefore, the authors propose an agent-based model along with a simulation environment to investigate user behaviour.

3 Simulation environment

The simulation environment is a Java-based web-based server application build with open-source components. It is using the MASON multi-agent simulation toolkit (Luke et al. 2005) and the Spring MVC framework (spring.io 2017). Its overall software architecture is shown in Figure 1.

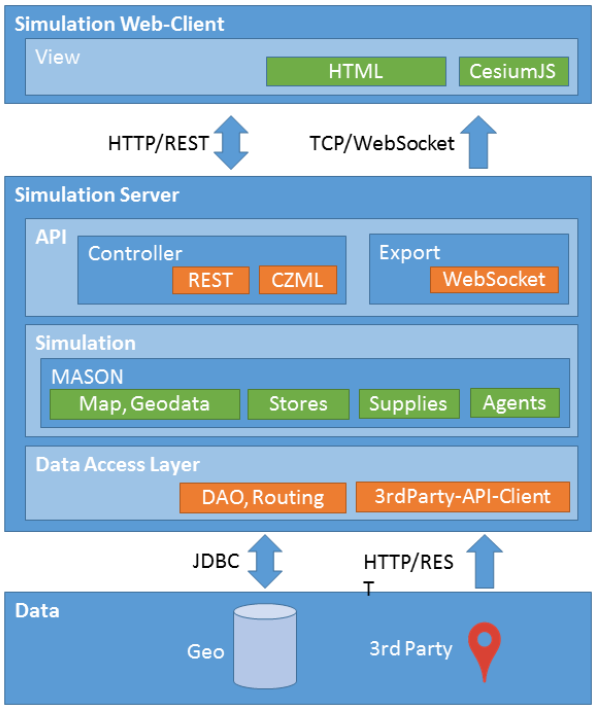

Figure 1: Conceptual view of AMiCUS software architecture

Algorithms within the simulation are using methods provided by GIS. Therefore, map and other georeferenced data is used. This data is stored in a PostgreSQL database using PostGIS extension (PostgreSQL 2017). All simulation related communication is performed in a real-time manner pushing data from server to web-client using web sockets (Saint-Andre 2011). The open-source component CesiumJS (CesiumJS 2017) along with the proprietary CZML data format is used to visualize the simulation within the client application. A screenshot of a running prototype simulation is shown in Figure 2.

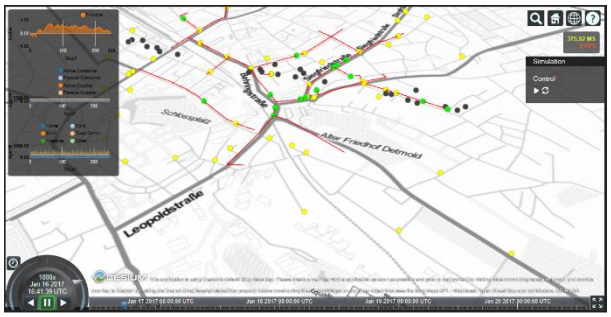

Figure 2: Screenshot of running prototype simulation

4 Proposed Model

This shortened description of the model is based on the three main blocks of Overview, Design concepts and Details (ODD) as described by Grimm et al. (2006). For the visualization of the model additional diagrams of the Unified Modeling Language (UML) are used (Bersini 2011).

Using the rural region Ostwestfalen-Lippe as an example, the model intends to estimate the success of the web-based and community-driven service through a simulation.

The proposed model consist of three entities: user agents as consumers (α), user agents as suppliers (β) and the community-based service itself (Γ). The agents are distributed as potential users of the system to households on all residential buildings ($\alpha_{homeLocation}$). The Agents are provided an additional set of locations ($\beta_{externalLocations}$) that describes their everyday destinations. The set was defined considering the definition of different trip purposes (Follmer et al. 2008). In addition stores at certain locations ($\Gamma_{storeLocation}$) reflect part of the system environment where agents interact. All building and road information of Ostwestfalen-Lippe region are used as ESRI shape file data source.

Consumers demand for supply (α_{demand}). Therefore, they will request goods in the future. Whether the users satisfy their needs using this service is determined by their own ($\alpha_{serviceKudos}$) and overall ($\Gamma_{serviceKudos}$) experience.

As soon as suppliers are outside their home location they become spatially mobile agents. While moving they can check for available requests for supply and accept them as supplier. The acceptance is based on three factors: additional cost ($\beta_{\Delta cost}$) for the detour to fetch and deliver the order as well as global ($\Gamma_{serviceKudos}$) and personal ($\beta_{serviceKudos}$) reputation of the system.

Figure 3 shows the entire diagram of an agent's activities for one simulation step.

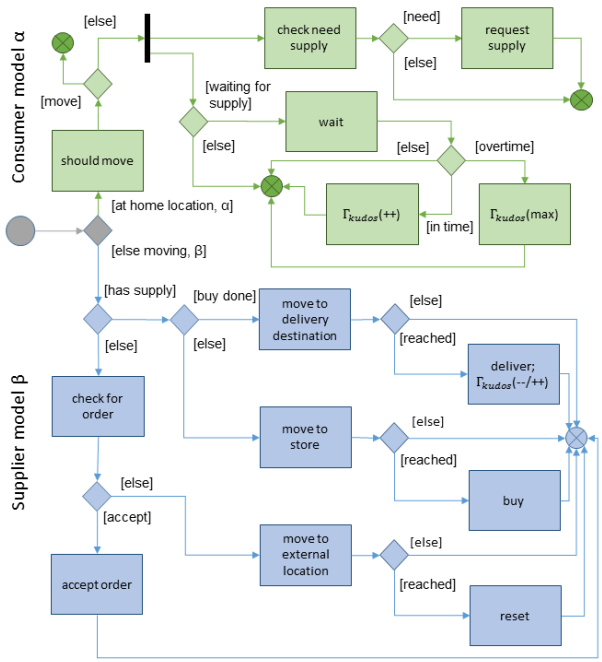

Figure 3: The agent-based model UML activity diagram

5 Future work

As the very next step the model will be implemented for further research. Several simulation runs will be performed to collect relevant data. Afterwards the verification of the model and the examination of the data is another important step.

Besides there are efforts to carry out the service as a pilot project for this region. In the end the simulation results could lead to a more sophisticated service experience due to knowledge of potential weaknesses and how to avoid them.

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