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Agent-Based Simulation of Medical Device Redistribution in Crises with Reinforcement Learning

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RL4AA'26 Poster Abstract

Background and Motivation
In crisis situations, hospitals can face shortages of medical devices required for the proper treatment of patients. More effective coordination of existing medical resources could therefore
improve patient care as well as the resilience of the healthcare system.

The objective of this work is to develop a spatial simulation that models the distribution of medical devices in crisis situations and supports decision-making on how devices can be allocated within a hospital network in an effective way to reduce shortages. A key aspect of this is the integration of geographic information, which allows the analysis of location-base relationships in relation to socio-demographic conditions, influencing planning and transport decisions. In addition, the simulation could be used to quantify the impact of different distribution strategies on the resilience of the regional healthcare system.

Methodology
The simulation combines agent-based modeling (ABM) with reinforcement learning. ABM agents represent entities such as hospitals or medical devices, while reinforcement learning is responsible for decision-making in the model. The learning objective is to reduce device shortages, while penalizing inefficient actions such as long-distance transport. We develop two simlation models to study the distribution of medical devices in crisis situations.

The base model represents a scenario in which multiple medical devices become unavailable across all hospitals due to a cybersecurity incident. Some hospitals experience shortages, while others still have enough devices and can potentially share them. The model simulates how
medical devices can be redistributed within the hospital network to reduce deficits.

The advanced model extends the base model by simulating a system overload caused by an infectious disease. Patient inflows are modeled based on geographic and socio-demographic
factors as well as hospitalization data, leading to simulated bed occupancy in hospitals. The resulting demand for medical devices is derived from the number of hospitalized patients. The device redistribution logic is then applied under these overload conditions.

The model is currently under development.

Expected Results
The simulation is expected to provide decision support for the distribution of medical devices during crisis situations. It enables the identification of critical load thresholds at which hospitals
become overstressed under specific crisis scenarios. Furthermore, the results are expected to demonstrate how device distribution strategies can increase the resilience of the regional healthcare system.

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