

**1307**

**K.N. Toosi University of Technology**

**Faculty of Geodesy and Geomatics**

**Ph.D. Thesis in Civil-Surveying Engineering**

**In GIS**

**Development of an Agent-Based Method for Spatial Task Allocation in Uncertain Conditions (case study: rescue teams)**

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# Abstract

Agent-based modeling (ABM) is a promising approach for developing simulation tools for complex phenomena such as urban search and rescue (USAR) operations. Task allocation in uncertain conditions is a key problem for agents attempting to achieve a harmony in multi-agent systems. The uncertainty in task allocation is challenging both practically and theoretically in disaster environments. The main objective of this research is to improve the process of task allocation and cooperation among agents in urban search and rescue (USAR) operations. Three main activities were carried out in this regard. At first, an agent-based approach was developed for task allocation to include interval uncertainty in agents’ decision-making. In the second step, spatial strategies were presented to consider uncertainty in the implementation phase. Finally, a dynamic agent-based simulation system in post-earthquake USAR operations was developed for Tehran’s District 3 to evaluate the proposed method. The main innovation of this research is using the concepts of interval uncertainty and presenting spatial strategies in the task allocation process of multi-agent systems.

In this thesis, uncertainties that were considered include the number of injuries, severity of the victims’ injuries, duration of the operation, infrastructure priorities, agent energy, route status, task runtime by an agent, risk level for agents and the remaining time of the task. The results were obtained by comparing the proposed method with the contract net protocol (CNP) at different scales, and in the presence of uncertainties in different quantities. On average, the proposed method was better than the CNP in terms of search and rescue (SAR) operation time (124 minutes), the number of dead people (8) and the number of incorrect allocations (180 tasks). To investigate the proposed spatial strategies, nine scenarios were generated for different number of tasks and agents. In comparison with contract net protocol (CNP), the standard time of rescue operations in the proposed approach includes at least 13%, on average 18% of improvement and the best percentage of recovery was 24%. Interval uncertainty analysis and the comparison of the proposed strategies showed that an increase in uncertainty leads to an increased rescue time for CNP of 870.9 minute, and for strategies one to four an increased rescue time 705.6, 692.3, 680.9, and 639.3 minute, respectively. With the implementation of the simulator system, the results of the proposed method were compared with CNP method in 27 scenarios. The average results for different scales indicated that considering the uncertainty in task allocation reduced the time of search and rescue operations to at least 16% and improved on average 27%. The results show that considering the interval uncertainty in task allocation can be a great advantage in USAR operations. In addition, by considering the uncertainty in agents’ decision-making and the implementation of allocation strategies, agents will be able to be prepared to deal with non-fulfillment of tasks.

**Keywords:** Task allocation; Interval uncertainty; Spatial strategies; urban search and rescue (USAR) operations; Multi-agent systems.