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学位論文名	Development of Algorithm for Multi-Criteria, Multi-Purpose Kinetic Routing Service Using Free and Open Source Software (フリーオープンソースソフトウェアを用いた多基準汎用動的経路探索サービスのアルゴリズム開発)		
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論文内容の要旨

Efficient management of vehicular traffic and people is an important issue especially in highly urbanized environment. Optimal routing on road networks needs to be addressed in case of emergencies as well as in normal situations. In recent times, sprawling cities are seen to increasingly experience sudden and unexpected localized downpours induced by urban micro-climate. While these unexpected events are difficult to predict, efficient computation and quick dissemination of information on alternative routes could be an effective way to minimize loss of lives and property in such emergency situations. GPS Navigation Devices and, more recently, Internet enabled mobile devices provide access to routing as well as traffic information. However, their effectiveness for more general-purpose needs is often limited as the technology provided is often of proprietary nature. Further, several of available navigation tools do not take into account dynamic factors that would curtail or even block transit on specific road segments.

This study aims at developing an algorithm for dynamic routing that could overcome several limitations seen in existing solutions. The present study outlines the development of a system for Emergency Routing Decision Planning (ERDP) based on Free and Open Source Software for Geospatial (FOSS4G), Open Data and Open Standards. A participatory framework based OGC Web Services (OWS) to manage and update data related to road conditions using mobile devices has also been implemented.

Firstly, ERDP functionality is developed by integrating Dijkstra routing algorithm and Analytic Hierarchy Process (AHP) algorithms. Routes are calculated considering situation at source, transit and destinations. The AHP is used to prioritize amongst possible destination considering impedance factors affecting travel time. This new and improved weighted travel-time algorithm is developed by extending the functionality of the Open Source pgRouting library.

Secondly, the algorithm is implemented as a Web application using Open Street Map data and FOSS4G tools such as PostgreSQL, PostGIS, MapServer and Openlayers. A jQuery-based mobile application has also been developed to facilitate ubiquitous access to the ERDP system. The deployment ERDP as Web application facilitates platform independence and easy dissemination of routing results based on up-to-date road network data.

Thirdly, the ERDP system has been designed to adopt a Service Oriented Architecture (SOA) for interoperability and scalability. SOA is enabled by using Open Geospatial Standards such as WMS and WFS for data oriented service and Web Processing Service (WPS) protocol for task oriented computational services. ZOO WPS implementation is used to provide routing and geoprocessing functionality via standard http requests from Web browsers. The routing services are also tested in indoor navigation using Scalable Vector Graphics for map data and visible light

communication for positioning.

The efficacy of ERDP system has been demonstrated considering two typical application scenarios. In the first scenario of a medical emergency, the ERDP computes routes to hospital in proximity of accident site considering dynamic factors such as conditions of road network, the patient's state and availability of medical facilities and expertise in the target hospital. In the second scenario of flood disaster situation, the GRASS GIS *r.sim.water* simulation model for overland flow under rainfall excess conditions was integrated into the ERDP system as a geoprocessing service. The result of the simulation is used to automatically update the road network database and new routes are computed based on condition of inundation.

The routing algorithm developed as a part of this research can be further improved by considering turn restrictions and temporary changes in traffic flow directions that can be anticipated in emergency situations. The ERDP system can be customized to support other emergencies such as fire, debris flow and tsunami. Automatic updates from allied data sources such as CCTV camera and weather stations using Sensor Observation Services standards need to be considered to further enhance system functionality for real-time ERDP.

論文審査の結果の要旨

The thesis examines the limitations of existing optimal routing solutions for road networks and presents a new framework for emergency route planning. The proposed multi-purpose ERDP system is capable of providing dynamic routing under normal as well as emergency situation and offers a highly flexible environment to deploy multi-criteria based dynamic routing solutions for a wide variety of applications. The main routing algorithm has been designed by combining Dijkstra shortest path algorithm with AHP to compute of minimum travel-time while considering many dynamic factors during transit and changing situations at alternative destinations. The algorithm is integrated as a Web application facilitating ubiquitous access to dynamic routing services on up-to-date road network data. Application of the ERDP Web services in case of medical emergency and natural disasters by using human and computer generated inputs to update conditions of the road network has been demonstrated. The ERDP framework is entirely based on FOSS4G, Open Data and Open Geospatial Standards providing a scalable, interoperable, customizable and cost effective solution that can be easily deployed and managed.

Further enhancement to routing algorithm considering traffic conditions and road geometry has been discussed. Incorporating other simulation models and seamless integration of indoor and outdoor routing services within the ERDP framework would promote utilization in for a variety of situations. Lastly, automating data acquisition from field sensor networks and service chaining for emergency route planning with minimal human intervention has also been proposed.

The research outcome described in the thesis not only demonstrates a methodical approach to the research problem but also an in depth knowledge of geospatial algorithm development and system implementation that the candidate possesses.

In view of the above, the present thesis was evaluated to be of high quality and as a significant contribution to the field of Spatial Information Science and Geoinformatics. Therefore, the examination committee unanimously recommends that the author of the thesis be awarded the degree of Doctor (Creative Cities).