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EMERGENCY RESPONSE TIME OPTIMISATION USING REAL-TIME TRAFFIC INFORMATION

Summary. This paper describes possible approaches for optimal route selection for emergency vehicles. The presented navigation software's architectures employ real-time traffic congestion information, matched to a tailored map. Four approaches have been described and reviewed against suitability in emergency response situations.

OPTYMALIZACJA DOJAZDU SŁUŻB RATOWNICZYCH Z WYKORZYSTANIEM INFORMACJI O RUCHU W CZASIE RZECZYWISTYM

Streszczenie. Artykuł prezentuje sposób optymalizacji obliczeń trasy pojazdu służb ratowniczych wykorzystując informacje o natężeniu ruchu uaktualniane w czasie rzeczywistym. Cztery możliwe architektury systemu nawigacyjnego zostały przedstawione i porównane pod kątem zastosowania w ratownictwie.

1. INTRODUCTION

The idea of saving time by selecting the quickest route to destination is older than invention of the wheel and first roads. Since reducing en route time results in lower costs, numerous industry-oriented research have been conducted in this area bringing beneficial solution mostly to road-based freight distribution operators (such as transport companies [1]). In case of Emergency Response (ER) services time mainly means priceless life. The situation gets much more complicated for fast moving ambulances in congested urban areas. Despite several attempts to optimise the distribution of ER bases throughout the city [2], meeting the benchmark time [3] which assumes reaching the scene in less than 10 minutes from the incident occurrence, remains a big challenge. As roads in the UK are three times busier than in Germany (and five times as busy as in France, Portugal or Austria [4]), the key to wade through the urban areas is selecting the most appropriate way basing on available knowledge of what is ahead. Although the ambulances' drivers perfectly know the roads' topology and usage pattern within their own service tract, the technology still has something to offer to win the time versus life race.

1.1. SCOPE

Since the turn of the century the focus in navigation industry has shifted from hardware towards smarter applications development. As Personal Navigation Devices with special modules can empower various types of long distance communication (FM-RDS, DAB, GSM, GPRS, EDGE, UMTS, set of IEEE 802.11 and 802.16 standards [5]) the possibility to create a solution utilising exchange of traffic information is no longer a challenge. The software architectures supporting such exchange can vary both in range of delivered data, sophistication and operational speed. Most of all, they need enable delivery of timely and relevant assistance to the driver. This paper will present how computerised route selection based not only on pre-defined path and car parameters but also on the current traffic flow data can assist in emergency, most of all in uncommon environments and circumstances, where time savings can be considerable. Next paragraph will focus where and how to obtain traffic information and digital maps, the third will describe possible frameworks to provide assistance and the fourth will suggest further development areas with future perspective.

2. DATA

Navigation's software algorithms calculate an optimal route basing on information kept in look-aside storage and those embedded in the digital map. The quality of itinerary is measured by its cost. Data on path parameters such as: functional and speed category, access characteristics, special attributes and current obstructions is used as weights in cost function. The best results of route calculation are achieved when this information is up-to-date and precise.

2.1. TRAFFIC INFORMATION

Traffic information lays a foundation for this project. Described with Ordnance Survey Grid Reference or WGS84 geographical coordinates [6], it is related to real world object called location. Traffic data sources can be classified in three time categories:

- Past road traffic patterns in urban areas can be generally depicted as in below figures. Congestion is mostly caused by commuting in private cars. Two peaks in Fig.1 correlate with typical 9 – 5 working hours. These profiles suggest the optimal time to send the emergency service. But this is not the case in urgency. As the rescue unit must be dispatched instantly, a time-of-day profile for each road needs to be analysed separately to distinguish, which path was least congested in the past under similar conditions. Solutions available on the market enable to create road usage profiles for streets in close neighbourhood of particular categories of land use (like industrial estates or food superstores [7]). These profiles can be processed by data mining tools to train neural network and develop static 3D map of land against congestion at particular hour, day of week, season and weather conditions.

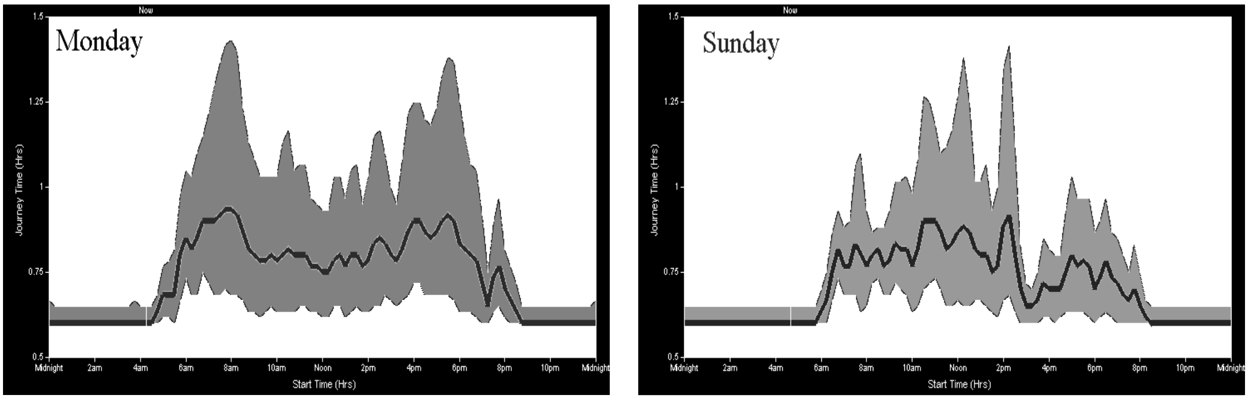

Fig. 1. Hour of day road profile. Edinburgh – Glasgow (65km) normal journey time and variance to be expected 8
Rys. 1. Godzinowy dzienny profil drogi. Edinburgh – Glasgow (65km) zwyczajny czas podróży oraz rozbieżności, których należy oczekiwać [8]

- **Current** traffic information are collected manually (Police, CCTV, "Jambusters", patrols) and automatically (Induction Loops, Video detection, Floating Car Data, Infra-red sensors, Weather sensors) to be further collated in local traffic management centres and private companies providing traffic information. Such data can be published via one of the traffic information exchange mechanisms (OTAP [9], TPEG [10], DATEX II [11]) bringing direct or indirect access to traffic measurement, expected delays, type of obstacles on roads in region of interest and many other features [6].

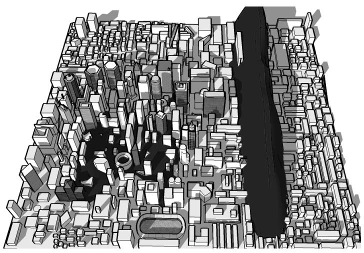

Fig. 2. Sample 3D map of averaged historic traffic volume at 5:30 p.m. on a working day
Rys. 2. Przykład mapy 3D historycznego uśrednionego rozmiaru ruchu o 17:30 w dzień roboczy

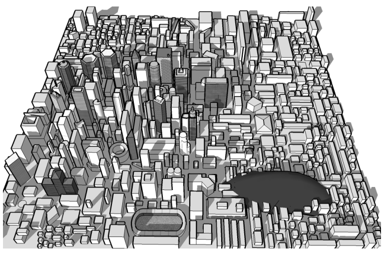

Fig. 3. Current data of traffic caused by road works
Rys. 3. Aktualne dane o ruchu spowodowane robotami drogowymi

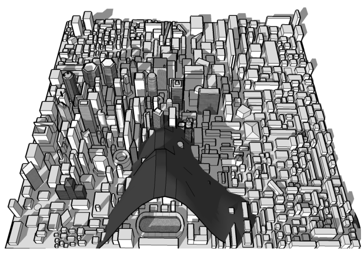

Fig. 4. Predicted congestion on the match day 1 hour after the game
Rys. 4. Przewidywane zagęszczenie w dniu meczu, godzinę po grze.

- **Future** road traffic patterns can be modelled if there is knowledge of a planned instance of the non-road event (concert, exhibition, sport event) or operation planned by traffic operator (transport of abnormal loads or road maintenance). Such information can be published for example via Scheduled Road Works [6] protocol describing time slot and possible range of influence. Another approach involves gathering information of expected attendance to a non-road event and its time frame. This way the gradient of traffic flow can be estimated and embedded in the city map [Fig.4].

2.2. TAILORED DIGITAL MAPS

Structured digital geographic information underlay operation of modern navigation software. Displayed in a form of map, contain various masked data relating to a single object such as road or intersection. One of the standards for digital road databases is Geographic Data File (GDF). It is an international format, coding information as sequential ASCII files. Road elements have functional, lane, and speed categories, can be described with access characteristics and have assigned special attributes. Maps are mainly produced to use in private transport, thus many features do not apply to priority vehicles. For example, speed category is typically the lowest speed limit on particular section. Other information can also be found redundant for use in emergency services. Using a dedicated parser, GDF can undergo adjustment, based on a survey among priority vehicles' drivers. Furthermore a map can be cut to cover just the local area where ambulances operate. Such confined map would be easier to handle both by hardware and software.

Proposed combination of historic statistic data with current average speeds and planned future events will help to tackle the dynamism of transport related issues for emergency response services. The next paragraph will present how these inputs can be delivered and formed in output assisting the driver.

3. ARCHITECTURES

To assist the driver a dedicated client–server information update mechanism needs to be developed. Four possible architectures are described and reviewed below.

3.1. ROAD BLOCK MECHANISM

Many Software Development Kits for navigation applications enable the newly developed external tool to add a rectangle to a list of avoided areas of the map. No road sections covered by such area are taken into consideration while calculating the itinerary [12]. The rectangle can be small to cover just a point on the road. If the point is placed on the intersection, all paths leading to it are "blacklisted". This enables to exclude all road elements meeting certain criteria: obstruction such as an accident, road works or speed of traffic flow lower than predefined threshold.

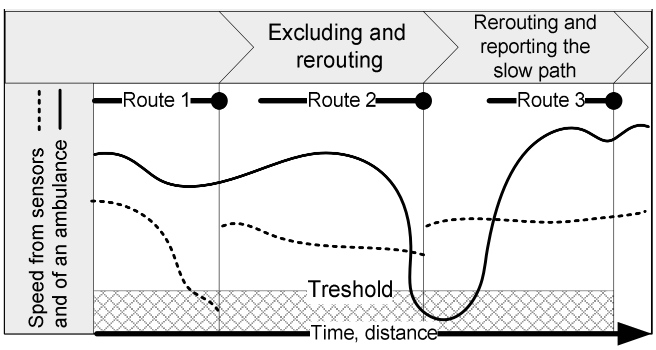

Fig. 5. Road block time phases
Rys. 5. Etapy czasowe odcinków drogowych

Furthermore, the client side application (running on a Personal Navigation Device) can temporarily"tag" the road element if the speed of an ambulance is far lower than expected. This tag is sent and added to traffic information database server and instantly “pushed” from the server to all connected units together with “reroute” command. This way any ambulance heading towards the ambulance caught in traffic will not take the same route.

3.2. LOCATION CODE TABLES CONCENTRATION

Supplied with special add-on, Personal Navigation Devices can receive Traffic Messaging Channel (TMC) signals [13]. They carry information in ALERT-C coding protocol of abnormal road conditions at particular points on the road. These points have unique id number and are stored in location tables together with relevant information, like their location. The maximum of 63,488[1] locations predefined by government are embedded in the map structure as special road attributes [14]. In the process of defining TMC location tables, highways and main transit paths are being prioritised due to limited number of locations, thus roads in metropolitan areas are barely covered. TMC messages reference particular place on the map and describe its condition – road works, accident, queues likely, length of the queue and many other. Itinerary calculation algorithms can automatically “reroute” basing on new path specification. And unlike in previous solutions the road parameters are not binary (clear / blocked) but in a way fuzzy, spreading path weight factors in range 0 – 1 for processing. What is more, the directions of traffic are distinguished.

As an ambulance usually operates in certain area, the solution to deliver comprehensive traffic information lays in redefining the location tables by assigning all entries to the points in the area of service. Adding a TMC attribute to road element involves parsing GDF map file by a tailored application and further converting it to a format proprietary for each navigation software provider.

On the server side, an application ascribes information from traffic management centre or predicted traffic pattern to the nearest point described in TMC location table and send an ALERT-C message in real-time. It needs to do so carefully, not to assign to a wrong traffic direction or wrong route.

3.3. INCREMENTAL MAP UPDATES

Currently the maps are updated “off-line” via storage media like DVDs or memory cards. One of the methods bringing in-vehicle up-to-date maps is the use on-line communication methods mentioned above to send a map with current traffic conditions as road attributes (speed category). Using certain scheme, GDF can be converted to an eXchange Meta Language format containing the same data but in different convention. An exchange mechanism comparing versions of data on the mobile device with the latest ones on the server side could push only these road parameters in region of interest which have been changed since the last update. Similar solution has been broadly described in one of the European Commission’s 5th framework projects – ActMAP [15]. Converting a map to a proprietary format needs a dedicated tool provided by a navigation’s software producer. Furthermore a GDF converted to XML is over 10 times bigger in size so an update mechanism needs to warily filter transferred information as the connection’s throughput in fast moving vehicle is limited.

[1] $2^{16 \text{ (the location is coded as 16 bit integer)}} - 2^{11 \text{ (reserved for pan-European routes)}} = 63{,}488$

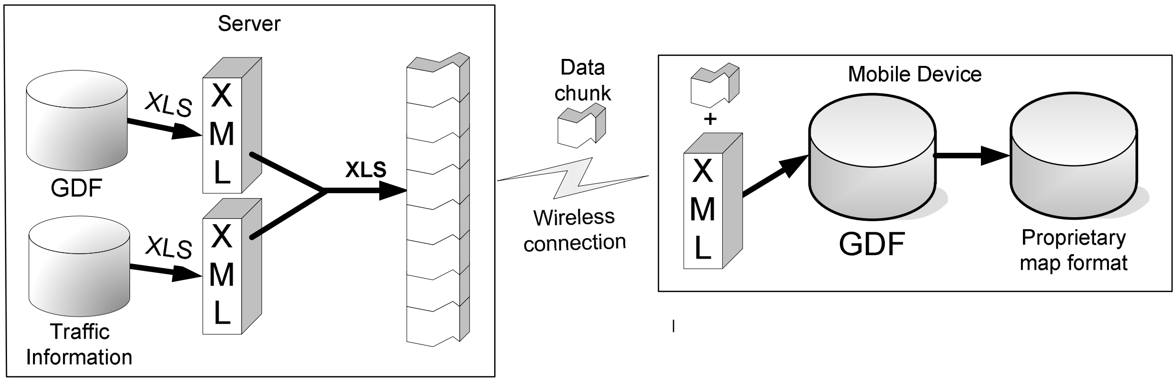

Fig. 6. Architecture behind incremental map updates
Rys. 6. Architektura stojąca za przyrostowym uaktualnianiem map

3.4. THIN-CLIENT ITINERARY SAMPLING

Tracking the ambulance's position gives possibility to suggest the best route from Emergency Management Centre's perspective [16]. A server connected to traffic information provider can do the entire itinerary calculations basing on reports of current position. Directions are then sent to a Personal Navigation Device to assist the driver. In case of lack of connectivity, such solution is backed up by the algorithm of Navigation's Software but without current traffic information.

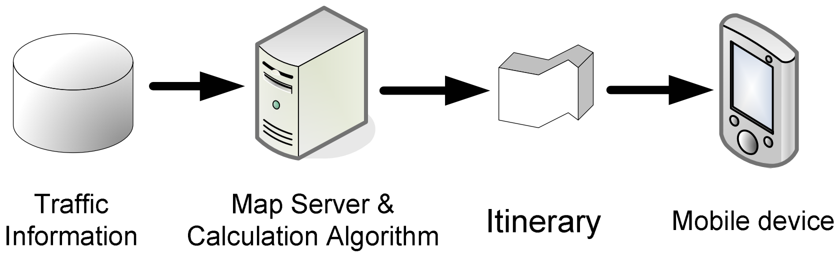

Fig. 7. Thin client itinerary sampling
Rys. 7. Słabe próbkowanie planu podróży odbiorcy

3.4.1. COMMUNICATION

To deliver current traffic information Vehicle to Infrastructure (V2I) connection needs to grant network access in a priority vehicle travelling at high speeds. Such delivery has to rely on existing, robust physical layers and open interfaces for protocol implementation. V2I communication is difficult for two main reasons – handover and Doppler Effect causing further InterCarrier Interferences (ICI). Ideally the communication layer(s) would provide a feedback channel closing the open loop of typical broadcasting methods. One of the available solutions combines en-route cellular communication (handling velocities up to 250 km/h) and wireless internet access used only in ER base as depicted in Fig.8.

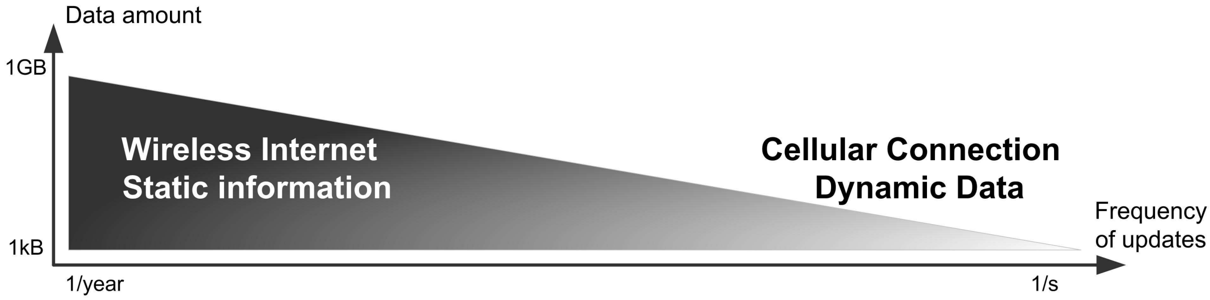

Fig. 8. Relation between frequency of updates and amount of data
Rys. 8. Powiązanie pomiędzy częstotliwością uaktualnień a ilością danych

4. SUGGESTIONS

Given that helpful assistance requires timely and relevant itinerary recommended to the ambulance's driver, software architecture needs to be simple and smart at the same time. The First solution seems to be the most basic one but a threshold of speed below which the road is excluded can be debatable [17]. The Third solution involves the conversion of a map into a proprietary format each time it is updated, as pure GDF is not used as a map. Such process requires deep computing which might outlast the interval between changes of road conditions. Last solution needs constant tracking to avoid sending directions to already passed route. Second solution, where the map has redefined TMC location table, involves map conversion into proprietary format just once. What is worth mentioning, such maps may be composed from separate files, one of which can be a location table, what makes reassigning much easier. This could lead to creating, interpreting and discarding location tables "on-the-fly" [18]. Such modification of second architecture would make pre-coding, maintenance and storage of location tables obsolete.

Establishing and operating dedicated FM-RDS signal is neither complicated nor expensive, but requires obeying broadcasting legislation [19] different for each country. Such broadcast can provide 300 messages during 5 minutes. Messages can not only be delivered by FM-RDS or DAB TMC broadcasting media but also cellular communication, allowing to send 220 messages every second at 8kB/s throughput.

Being able to confine the GDF map and reallocate its TMC locations to a specified urban area could bring desirable results keeping the system simple and robust. Yet such custom-built map coded as universal GDF can be adapted to any chosen navigation software assisting the driver and furnish ER services with solid base to deal with expiration of time in emergency. Moreover, minimisation of ambulance's travel time in cities with dense road network can improve the quality of health service for all citizens and influence how health care providers are perceived by public.

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