BUMPY

PAVEMENT QUALITY MEASURED BY STARSHIP DELIVERY ROBOTS & ROUTE OPTIMIZATION

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BUSINESS PROBLEM

Most modern-day delivery services rely on automated route optimization algorithms, that estimate optimal delivery routes, given the number of delivery vehicles, payload, and time constraints. While these algorithms can become very complex, they often discount pavement quality as one of the important conditional variables. Pavement quality is an important factor in route optimization, since it affects delivery time, energy consumption, and maintenance costs. In case of fragile packages, it may also affect the condition of the package.

So far, measuring pavement quality in a dynamic manner has been too difficult to justify measurement costs. Luckily, it has become more feasible with modern technology. Given gyroscope, accelerometer and GPS input from delivery vehicles, such as Starship delivery robots, companies are now able to periodically measure pavement quality in an automated and relatively low-cost manner. This input can be used to enhance route optimization algorithms, save delivery time, lower maintenance costs, and improve client satisfaction.

Figure 1: Map with optimal route

FROM JSON TO DATA FRAME

The original JSON data was composed of 40GB of JSON files which had to be read in and processed line by line (rjson). The key element in this task was speed, which is why the algorithm relied on data.table and avoided pipes. The original data consisted of numerous measurements for each second, but was aggregated to a one-second level for further analysis.

botid	timestamp	coordinates_long	coordinates_lat	heading	stdev	orientation_delta_x	orientation_delta_y	orientation_delta_z
6D100	1501488035	24.65780	59.40045	1.8571385	0.04239700	1.244122e-04	-2.005811e-04	1.050572e-04
6D100	1501488036	24.65784	59.40044	1.8558600	0.04323900	-1.511024e-04	8.648776e-05	3.244130e-04
6D100	1501488037	24.65787	59.40044	1.8358835	0.03464050	2.879247e-04	-5.113374e-05	4.090558e-04
6D100	1501488038	24.65790	59.40043	1.8238430	0.03282950	5.800761e-05	-2.721197e-04	-2.125552e-04
6D100	1501488039	24.65793	59.40043	1.8411095	0.03216150	-2.759987e-04	4.220136e-05	-5.777629e-04
6D100	1501488040	24.65797	59.40043	1.8554100	0.03404100	-4.687227e-05	-3.273424e-05	4.773369e-04
6D100	1501488041	24.65799	59.40042	1.8308885	0.03578650	6.636437e-05	-1.051164e-04	-3.971644e-06
6D100	1501488042	24.65802	59.40042	1.8324350	0.03056400	-3.034495e-05	7.253531e-05	2.313451e-04
6D100	1501488043	24.65805	59.40041	1.8217815	0.03411250	-2.533733e-04	2.322809e-04	-1.795112e-03
6D100	1501488044	24.65807	59.40041	1.8661690	0.02885000	6.385756e-04	-4.772474e-04	-2.389418e-03
6D100	1501488045	24.65810	59.40041	2.0281753	0.03629633	-9.449826e-04	2.929401e-04	-3.169243e-03
6D100	1501488046	24.65812	59.40040	2.1060095	0.03137550	1.494863e-04	3.429219e-04	-5.894398e-03
6D100	1501488047	24.65814	59.40040	2.4406560	0.02761933	-1.693393e-04	-3.359524e-04	5.641778e-04

Figure 2: Example of main dataset

ANALYZING PAVEMENT QUALITY

For measuring pavement quality a custom formula was used, focusing on the up-down movement of the robot (vibration intensity). The formula used variation in the accelerometer and gyroscope z-axis for that purpose. The results were normalized for easier interpretation.

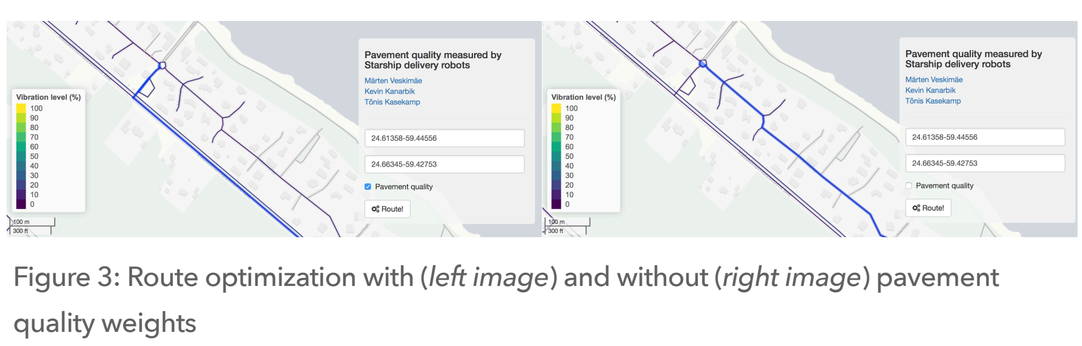

Figure 3: Route optimization with (*left image*) and without (*right image*) pavement quality weights

ROUTE OPTIMIZATION & VISUALIZATION

In order to visualize pavement quality and perform route optimization, the raw GPS data from delivery robots had to be linked with Tallinn's road network. For this OpenStreetMap data was used (osmar) and visualized via leaflet (mapview; leaflet). For route optimization, Road network's nodes were weighed by the road quality indicator and transformed into a graph object, after which the shortest path was calculated (igraph). The final application was implemented using shiny.

Try out the *almost* stable demo version here:

https://goo.gl/SNxrCR