Solid Waste Collection and Management using Smart Algorithm based on Genetic Programming

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Abstract. According actual environmental policies, problem of solid waste collection is one of the significant priorities of many different municipalities. Starting from the map of solid waste containers as an initial condition, the given pilot model in this paper, try to solve the mentioned problem for municipality of Prilep. The main goal of this model is to reduce transport costs, based on control of two parameters: container filling, and routing optimization. For this purpose, depending on the frequency, time and extent of filling, it needs to be created and constantly revised a sub-map with containers, as a subset of primary map. Route optimization for those subset maps, is made using modified smart algorithms from subfields of artificial intelligence.

Keywords: Vehicle Routing problem, optimization, waste management,

1. Introduction

Modern ways of living continuously produces significant amounts of urban solid waste. According Eurostat data Costs for everyday processes of waste collection, and transport to landfill, represent an important financial share in the municipal budget. Each municipality, according ecological and financial points of view, should analyze situation and bring a sustainable multi-criteria waste management process. In order to optimize whole process of collection and transport, routes should be optimized for those subset maps.

The number and location of containers changes periodically, which lead to need of re-calculation of subset of primary map. Continuously, the level of fullness of container is changing, and, this information should be used as a selection criteria, which containers are parts of following route and needs to be emptied. Described activities need to be done for purpose to ensure quality data input for smart algorithms.

All those activities are planned and performed according two main purposes: to ensure quality management of waste collection process from the ecological point of view; and, the same time, to minimize financial implications and costs. For a long time, whole solid waste quantity measurements across the world show a growth trend of quantity, leading to increased costs of collecting, transporting and disposing. Independently of waste quantity, there is always a possibility to manage with municipal waste collection following some ecological recommendations. Also, there is an opportunity to decrease transport costs, using smart algorithms for optimizing working trajectories of waste vehicles. According Eurostat [1], municipal waste accounts for only about 10 % of total waste generated when compared with the data reported according to the Waste Statistics Regulation. Table 1. present statistical trends, collected and published data on municipal waste since 1995. These data are widely used for comparing municipal waste generation and treatment in different countries, and indicators on municipal waste are used to monitor European waste policies. The data on municipal waste expressed in kilograms per capita are part of a set of indicators compiled annually to monitor the EU's sustainable development strategy, and shown decreasing trend.

Table 1. Municipal waste trends in EU from 1995-2015 [1].

	1995	2000	2005	2010	2015	change (%) 1995-2015
EU-28	:	521	515	504	476	:
EU-27	473	523	517	505	476	1
Belgium	455	471	482	456	418	-8
Bulgaria	694	612	588	554	419	-40
Czech Republic	302	335	289	318	316	5
Denmark	521	664	736	:	789	52
Germany	623	642	565	602	625	0
Estonia	371	453	433	305	359	-3
Ireland	512	599	731	624	:	:
Greece	303	412	442	532	485	60
Spain	505	653	588	510	434	-14
France	475	514	530	533	501	5
Croatia	:	262	336	379	393	:
Italy	454	509	546	547	486	7
Cyprus	595	628	688	689	638	7
Latvia	264	271	320	324	404	53
Lithuania	426	365	387	404	448	5
Luxembourg	587	654	672	679	625	6
Hungary	460	446	461	403	377	-18
Malta	387	533	623	601	624	61
Netherlands	539	598	599	571	523	-3
Austria	437	580	575	562	560	28
Poland	285	320	319	316	286	0
Portugal	352	457	452	516	:	:
Romania	342	355	383	313	247	-28
Slovenia	596	513	494	490	449	-25
Slovakia	295	254	273	319	329	12
Finland	413	502	478	470	500	21
Sweden	386	428	477	439	447	16
United Kingdom	498	577	581	509	485	-3
Iceland	426	462	516	484	583	37
Norway	624	613	426	469	421	-33
Switzerland	600	656	661	708	725	21
Montenegro	:	:	:	:	533	:
The former Yugoslav Republic of Macedonia	:	:	:	351	:	:
Serbia	:	:	:	363	259	:
Turkey	441	465	458	407	400	-9
Bosnia and Herzegovina	:	:	:	332	:	:
Kosovo*	:	:	: :		178	:

(:) not available

(*) This designation is without prejudice to positions on status, and is in line with UNSCR 1244 and the ICJ Opinion on the Kosovo Declaration of Independence.

Waste collection is the collection and transport of waste to the place of treatment or discharge by municipal services or similar institutions, or by public or private corporations, specialized enterprises or general government. Collection of municipal waste may be selective, that is to say, carried out for a specific type of product, or undifferentiated, in other words, covering all kinds of waste at the same time. [2].
Regarding the use of smart algorithms for vehicle routing optimizing, the last decades, many researchers searching for solutions, have modeled this problem on various ways and versions, such as: vehicle routing problem [3], [4], sometime, for the improvement purpose, combined with other computational techniques, capacitated arc routing problem [5], ant routing problem [6], and different kinds of traveling salesman problem [8]. An smart algorithm modification is presented in this paper, based on symmetric traveling salesman problem [7], which use authentic data for locations of different kinds of waste container [8]. The following sections will explain necessary steps formulating problems and finding solutions.

2. Solid waste collection modeling – Municipality of Prilep case study

According to reports and statistic indicators from the company "Komunalec", Municipality of Prilep, there are a few different kind of containers, depend of garbage and users profiles. For example, there are 20315 households that use small waste bins, and fixed timetable for waste removal (1 time per week, in planned days). But, there also, 33 facilities for educational purposes, such as kindergartens, primary and secondary schools, and colleges, and 1417 different kinds of business entities, which share larger containers, all of those, located according Fig.2.

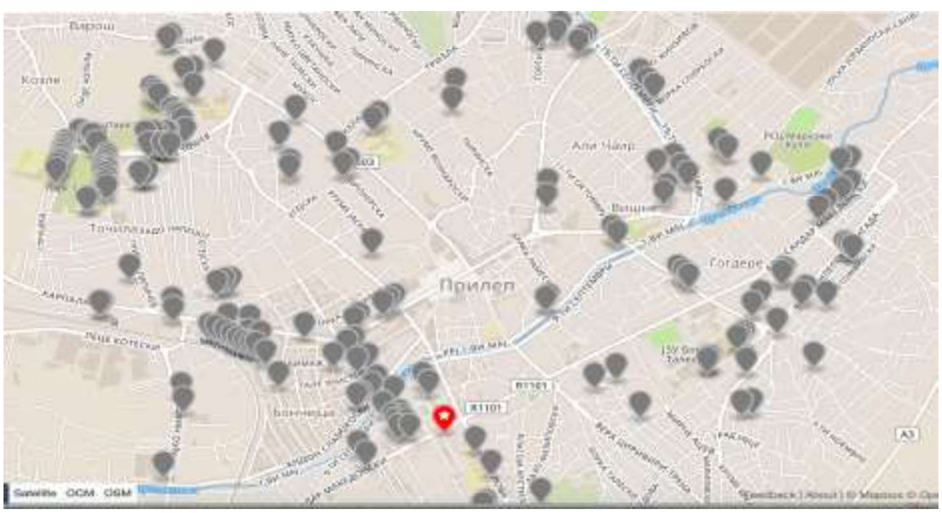

Fig.2. Solid waste containers and bins in Municipality of Prilep

Large and peripheral containers are visited according to a special plan, based on solid waste collection statistic from past years. The containers of central urban area, as can be seen, are naturally grouped by location, and marked on schema. The further assumption in this paper is that the observed streets are two-way, which corresponds to reality. Furthermore, starting from coordinates od map, according to Manhattan metric, which means that it is sufficient to calculate the distance between different groups of containers and use as input parameters on the distance matrix. Any particular container of each group should be equipped with sensor for fullness measurement. Before routing, according to those measurements and capacity of vehicles, it is possible to make simulations and fin optimal number of vehicles which are necessary for collecting the detected waste.

3. Smart Algorithm implementation

The continuous growth of power of processors and computer systems in the last decades, enable a new approach for difficult problems solving. Further, a new chance is given, to solve some mathematical and technical problems, which have high demands for processing, known as “brute-force”, on a completely new way. This new possibility, based on biological inspired techniques, is given through paradigm called evolutionary computation.

3.1. Evolutionary computation

All biologically inspired techniques for real problem solving, widely known and described under the term evolutionary computation have some common characteristics. Primary advantage of evolutionary computation is that is conceptually simple, but not always easy for use. That’s because every successful implementation needs imagination and ability to translate real model and process on the level to be comparable with natural processes of evolutions. Depending on variations of basic parameters, there are a few basic evolutionary categories, known as: Evolutionary algorithms, Evolutionary strategies, Genetic algorithms and Genetic programming. All of those, have some common functional characteristics, as well:

- Initial population, formed from
- Individuals, represented with chromosomes
- Number of generations planed to convergent to
- Adequate solution,
- Set of operators, like mutation, crossover, tournament selection, used to make changes of initial population,
- Fitness function defined as a convergent criteria, and finally, the
- Problem space which represent union of all possible solutions that satisfy the given conditions.

The problem space is actually made from all individuals which tend to be adequate solution. Each individual, called also, genome or chromosome, have some potential to be solution. The same process of founding solution is made from activities which change genomes and individuals, on way to be best possible adopted according the fitness function demands. All categories of evolutionary computation, are based on meta-heuristic and stochastic optimization, which means, to seek for optimal solution from problem space. But, unlike the deterministic method, where it is always possible to get a solution with the desired accuracy, stochastic methods do not guarantee finding the global optimum, or the required accuracy. Genetic programming is most advanced technique in evolutionary computation. The main advantage over other evolutionary techniques is the way to generate the chromosome, which represent individuals. Chromosomes created using other evolutionary methods, have only values, but those used in genetic programming, are parsed GP tree on values and functions. The choice of parameters and operators in genetic programming, has goal to make modification of parsed tree, and lead to faster solution.

3.2. Smart algorithm implementation for municipal solid waste collection and routing optimization – Municipality of Prilep

According previous explanations, it is necessary to mark container locations on map of MoP, further used to calculate distance matrix for loading spots, in central area. According to the real situation, some working assumptions are made in this research:

- All used streets in urban area are two-way,
- The containers and bins are equipped with waste level sensors [9]

Problem which has to be solved is: how to make optimal schedule, to visit all loading spots in central area city , depend of following presumptions and needs: to optimize routing process of vehicles, and to find the smallest number of vehicles needed for collecting waste, according the measured level of each particular container. A series of initial experiments has been made, at first, for whole city according Fig.2., and later, according container positions show on Fig.3.

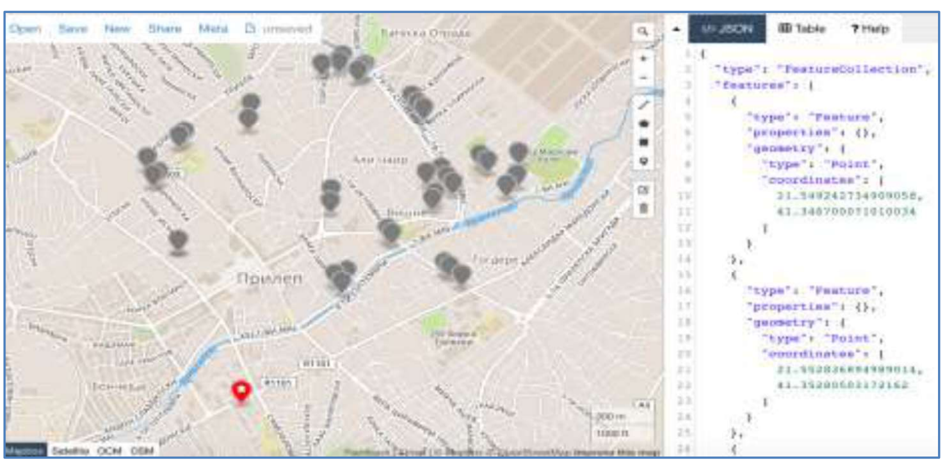

Fig.3. Solid waste containters shema - Gjogdere, Alichair, Visne and part of Center

In situation when a smart VRP algorithm was used, for a whole Prilep town, the following results were obtained: the route is optimized, the total length is reduced, the required number of vehicles depends on the amount of waste. According optimization processes, this leads to a conclusion that the sensors for quantity measurement, are useful. On the other hand, the containers are unevenly distributed, for which, the obtained trajectory, although the shorter are unpopular.

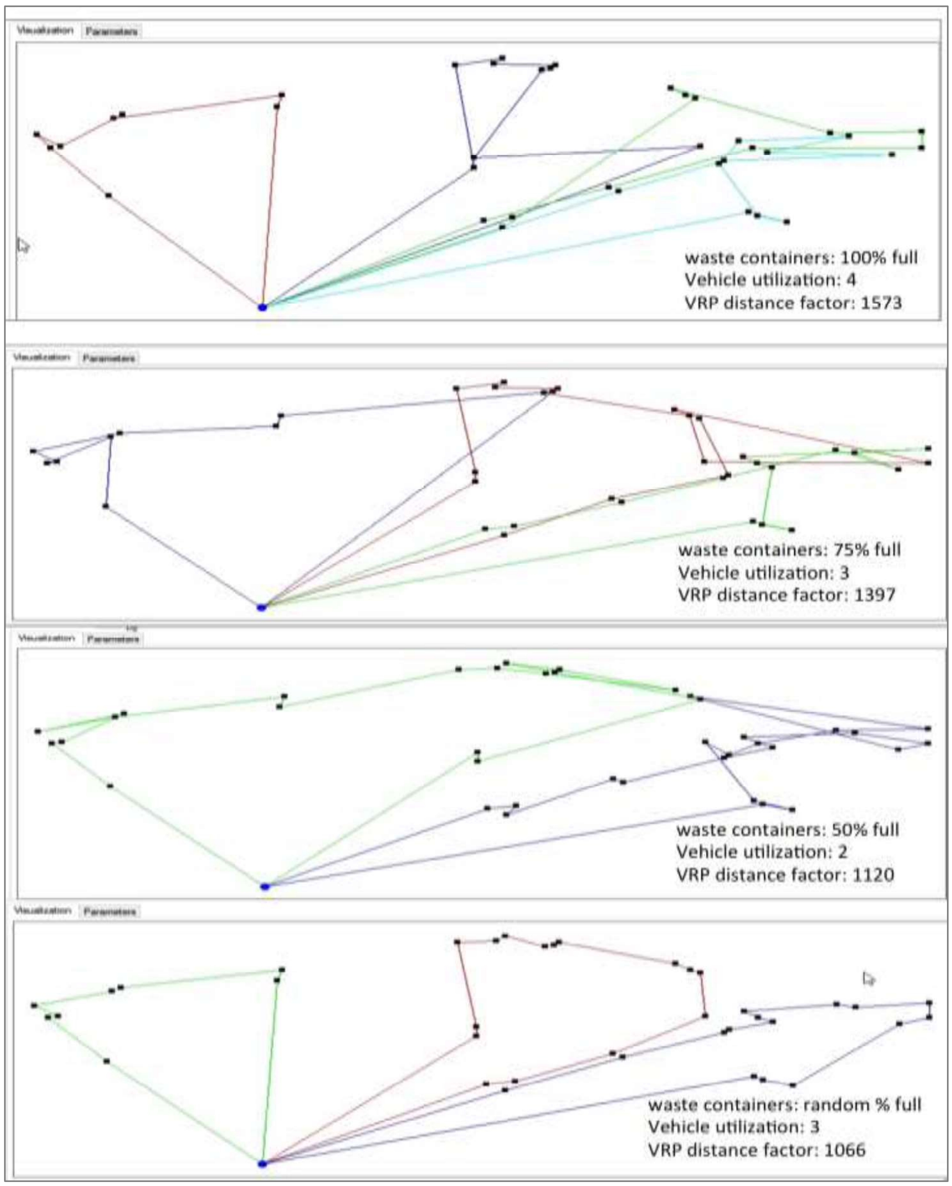

Fig.4. Experimental results – solid waste collecting and routing MoP

Instead of the whole city, it's better to make optimizations for particular quarts, based on grouping waste containers. In this case, it is possible to manage the number of vehicles and optimize routing, and, at the same time, achieve logically acceptable trajectories. In purpose better explain this idea, an quart in Prilep is selected, called AliChair-Visne-Gjogdere, which include 39 container locations. Starting point for routing is location of the company Komunalec, situated in urban area (marked with star on Fig.3.). Open source Leaflet Routing Machine, and GeoJson, are used to pick waste points coordinates (latitude and longitude, Fig.3) and transform it into Manhattan distance. Experimental results of algorithm use are presented of Fig.4.

3.3. Intepretation of results

According to the assumption that the input data on the amount of garbage are available for each container, there are 4 experiment: 100%, 75%, 50% of fill, and random generated amount %, for each container particularly. The data on percentage of container occupancy are assumed. The number of container is continuously 39, according the current situation. Depending of amount of the waste, there are various number of vehicle, 2,3, or 4, which is one more segment of optimization. It is also possible to conclude a continuous shortening of the routes. Furthermore, irrespective of the fact that during the algorithm process, the graphical route views are straight lines, these are calculated according real street geometry in Prilep, using as it said previous, Manhattan distance. Smart algorithms, as mentioned above, give the results that are most appropriately accepted at this point of observation, but not necessarily the best possible. The more factors being taken into analysis, the greater the likelihood and the possibility of optimization.

4. Conclusion

Solid Waste Management is one of the most influential financial processes of each municipal budget. Therefore, any savings in this process are of importance. One of the way how to improve it, is continuous adaptation and improvement of basic processes of waste collection. In the waste management process itself, there are the elements which are variable, which need to be predicted and calculated. Smart algorithms, as explained above, have great potential for use, which is why they are the subject of research for several decades. Presented results in this work has shown advantages and obstacles of smart VRP algorithm use: For better optimization, it is recommended to process container fullness information, city segmentation in the waste collection area, and the route re-calculation before the collection process begins. This work can be upgraded, using real data for sensor measurements, and perform calculation for other city areas.

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