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Fuzzy Logic Application for Routes Planning and Optimisation

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Abstract. This presentation deals with the mathematical models of vehicle routing problem (VRP) in uncertain functioning conditions. The interactive approach, synthesis of decision-making algorithms and mathematical models for increasing efficiency of VRP solution are considered. The most important accent of the paper is a fuzzy approach to solving various optimization problems for cargo transportation. The mathematical models and numerical examples of the VRP for several stages and optimization tasks with discussion of fuzzy peculiarities of various functioning conditions are presented.

Introduction

Fuzzy sets theory and fuzzy logic is widely introducing to research and design practice last years. Especially it is important and effective for control of such objects with non-stationary functioning conditions as aircrafts, ships, underwater robots and other. Special attention should be paid to solving transportation problem as problem in fuzzy environment. At the general statement transportation problem minimizes the cost (goal) function concerning to the transportation of various kind of cargoes (oil, coal, fuel etc.) from several (or one) supplying ports (depots) to various receiving ports (nodes). It is very important to solve transportation problems from the viewpoint of changeable character of functioning conditions as problem in fuzzy environment. Intelligent technology, fuzzy systems and neuro-systems can help to solve transportation problem in uncertainty efficiently.

Some published models, decision-making algorithms, practical examples and modelling results which deal with the application of optimization methods to the solving different transportation tasks are considred in the presentation.

The main goal of this presentation is to consider fuzzy approaches with application to capacitive routing problem as problem in fuzzy environment.

Fuzzy Approach for CVRP Solving

One of the most important vehicle routing problems (VRP) is routing problem for bunkering tankers. Such kind of tankers should provide bunkering (transportation and unloaded) operations for various served (ordered) ships which can be located in different marine ports and open sea points. Marine practice shows that very often the information about fuel demands of served ships and ports is uncertain. It is possible to represent such kind of orders as fuzzy demands $\tilde{q}_j = \left(\underline{q}_j, \hat{q}_j, \overline{q}_j\right)$ with triangular membership function, where $\hat{q}_j$ is a value with $\mu\left(\hat{q}_j\right) = 1$; $\underline{q}_j$ and $\overline{q}_j$ are the lowest and highest possible values of demand, respectively, $\mu\left(\underline{q}_j\right) = 0$, $\mu\left(\overline{q}_j\right) = 0$. Taking in to account the restricted fuel capacity of each tanker and fuzzy demands of ordered ships the well-known VRP will transfer to capacitate vehicle routing problem (CVRP) in uncertainty. The efficiency of preliminary bunkering operations planning is evaluated by possibility to serve all ordered ships with maximum of possible quantity of unloaded fuel and with minimum of the total length of tankers' routes.

Let's consider depot P_0 where bunkering company is located and fuzzy approach based on the application of relative signals for fuzzy system provided solving CVRP in uncertainty. The decision-maker of bunkering company needs solving tanker's CVRP before beginning of any bunkering operations. At the deport P_0 bunkering company have m tankers for bunkering operations at the served marine region $(P_1...P_{12})$ and warehouse with satisfied quantity of fuel for any real set of demands of n ships which need fuel supplying for their further performance and mission continuation. Each i-th tanker ($i = 1,.., m$) has the varies fuel capacity Q_i, the served ships have various capacities S_j and various demands q_j $(j = 1,...,n)$, respectively. The decision-making by fuzzy system about including considered port P_{j+1} to current route will be based on the condition $\lambda_{J+1} \geq \lambda^*$, where λ^* is preference value; λ_{J+1} is a current value of satisfaction level which is calculated at the each served port (P_j) as possible level for next port (P_{j+1}) serving taking in to account its fuzzy demand q_{j+1}. The developed decision-making algorithm based on the fuzzy logic can be presented as follow:

$$\lambda_{j+1} = FIE\left[FRB\left(\underset{\sim}{x}_1, \underset{\sim}{x}_2, x_3\right)\right], \tag{1}$$

where FIE – fuzzy inference engine ; FRB – fuzzy rules base with followed structure of fuzzy rules "**IF** (input signal $\underset{\sim}{x}_1$ is *Low*) **AND** (input signal $\underset{\sim}{x}_2$ is *Middle*) **AND** (input signal x_3 is *High*) **THEN** (output signal λ_j is *High*)"; λ_{J+1} is satisfaction level for each alternative decision-making; $\underset{\sim}{x}_1 = \tilde{q}_{j+1} / \Delta\tilde{Q}_i$ is relative unit between fuzzy demand of next $(j+1)$-th port $\tilde{q}_{j+1}$ and fuzzy value of remain tanker cargo $\Delta\tilde{Q}_i$; $x_2 = \Delta\tilde{Q}_i / Q_i$ – relative unit between fuzzy numbers $\Delta\tilde{Q}_i$ and tanker capacity Q_i; $x_3 = L_1 / L_2$ is relative unit between length L_1 and L_2 of two alternative routes R_1 and R_2 (R_1 is route with 1st level of search of next port as candidate to route and R_2 is route of 2nd level of search; $\Delta\tilde{Q}_i$ is a fuzzy value of remain tanker cargo, where k is a number of served ships on the i-th route before decision-making process; $\{Low, Middle, High\}$ - set of the corresponding linguistic terms. The main criteria E_{BP} for evaluation of bunkering process efficiency based on solving CVRP with capacity constraints and fuzzy demands of served ships can be presented as

$$\max E_{BP} = \frac{1}{r}\sum_{i=1}^{r}\left(1 - \frac{\Delta Q_i^{remain}}{Q_i}\right), \tag{2}$$

which can be transformed to the form:

$$\Delta Q_i^{remain} \rightarrow \min, \ (i = 1, 2, \dots, r);$$

$$r \rightarrow \min,$$

where ΔQ_i^{remain} – remain fuel capacity before tanker returning to depot P_0; r – number of routes.

Conclusions

The proposed fuzzy system allows solving CVRP in fuzzy conditions, results of experiments and imitating modelling confirm efficiency of the developed algorithms and models for optimization of cargo transportation process accounting fuzzy peculiarities of environment.