The route-first cluster-second principle in vehicle routing

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Some classical heuristics for the VRP are based on the cluster-first route-second principle, for instance the sweep heuristic from Gillett and Miller (1974). In contrast, the route-first cluster-second principle has been seldom used. Beasley (1983) suggested some heuristics based on this principle, but without numerical results.

The talk will show that the route-first cluster-second principle can lead to effective heuristics and metaheuristics. We started using this principle successfully to evaluate chromosomes encoded as giant tours (or TSP tours, i.e., without trip delimiters), in a memetic algorithm (MA) for the VRP (2004). The procedure called *Split* builds an acyclic auxiliary digraph, in which each arc represents a feasible subsequence (trip) of the giant tour. The optimal splitting, subject to the sequence, corresponds to a shortest path in this graph. This idea is interesting since there is no loss of information: a VRP solution can be deduced optimally from each giant tour and it is easy to see that there exists one optimal giant tour (one giving an optimal VRP solution after splitting). Moreover, the MA explores a much smaller solution space.

The principle can be transposed to arc routing problems like the Capacitated Arc Routing Problem or CARP (2004) and the Mixed CARP or MCARP (2006). In general, many constraints met in practice concern the trip level: trips which do not satisfy such constraints are not included in the auxiliary graph but the shortest path computation is not affected. For instance, we obtained excellent results by developing ad hoc versions of *Split* in MAs for the Split Delivery VRP (2007), the CARP with Time Windows (2007), the VRP with Time Windows (to appear) and the Vehicle Fleet Mix Problem or VFMP (2006).

In 2006, we studied a more complex case for the periodic CARP or PCARP, motivated by municipal waste collection. The hierarchic objective function includes the number of required vehicles and the total cost of the routes over the horizon. We designed an MA and a scatter search (2006) which can be easily transposed to the periodic VRP. Each solution is encoded as a sequence of sub-chromosomes (one per day), and each sub-chromosome as a giant tour, like in the MA for the CARP. It is still possible to split such chromosomes optimally and in polynomial time. The Heterogeneous Fleet VRP (HFVRP) is even more involved because it raises a resource-constrained shortest path problem in the auxiliary graph. However, we developed a pseudo-polynomial version of *Split* which is fast enough in practice (2006).

Applications of the splitting principle are not limited to population-based metaheuristics. Recently, we designed for the VRP an Iterated Local Search (ILS) which alternates between giant tours and detailed VRP solutions. This method (forthcoming) becomes the second most effective metaheuristic for the VRP, just after the Active Guided Evolutionary Strategy (AGES) of Mester and Bräysy (2005).

Only recently, we compared simple splitting heuristics with traditional constructive heuristics for the VRP, to bring the numerical evaluation missing in Beasley (1983). In general, splitting an optimal TSP solution does not give an optimal VRP solution. Surprising results (forthcoming in IJPR) are obtained by applying *Split* to a set of giant tours generated by a randomized TSP heuristic.