Adaptive Large Neighborhood Search applied to mixed vehicle routing problems

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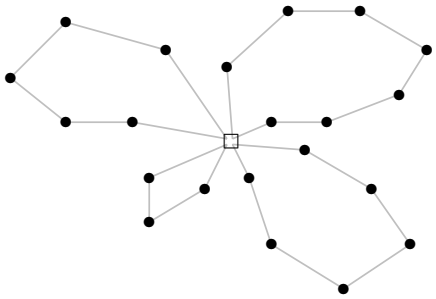
NEXT workshop 2006



Vehicle Routing Problem

Depot	Multiple depots
Customers	Site dependant
Vehicles	Pickup-delivery
Capacity of vehicle	Backhauls
Time windows	Open VRP

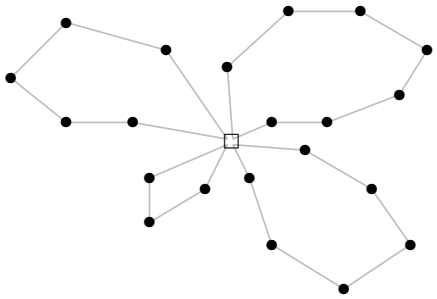
Storeroom optimization (MBS)
Exact methods (Jepsen, Petersen, Spoorendonk)
Heuristic methods (Pisinger, Røpke)

Motivation

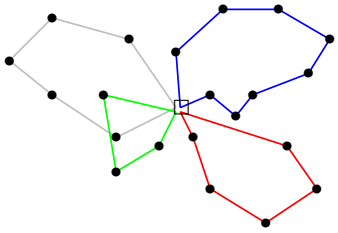
- Unified algorithm, several VRP variants
- Automatic parameter tuning

Adaptive Large Neighborhood Search

- Framework for combining several solution approaches
- Based on Large Neighborhood Search
- Applied to 12 variants af VRP
- Encouraging results (improved 40% instances)

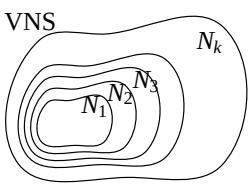


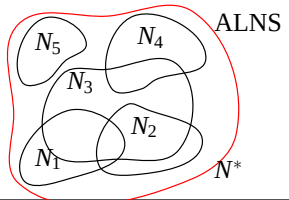
Adaptive Large Neighborhood Search



- Local search framework
- Simple algorithms compete to modify current solution
- Choose algorithm to *destroy* solution
- Choose algorithm to *repair* solution
- Accept new solution according to local search framework
- Choose *destroy* and *repair* alg. based on past score

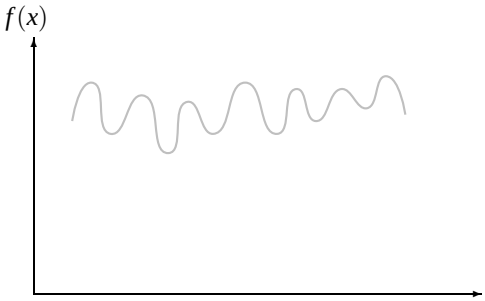
Extension of LNS (Shaw [1998]) VNS (Hansen and Mladenovic [1999])





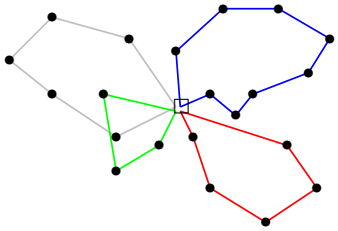
Properties of ALNS

Large Neighborhood Search



- Suited for tightly coupled problems where small neighborhoods cannot escape local minima
- Robust to changes in input, structure of instances
- Calibration quite limited
- The more reasonable neighborhoods the better performance
- Not “either-or” but “both-and”

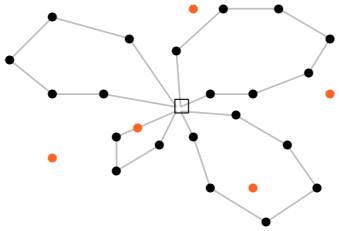
Destroy Nighborhoods



Given a solution x remove q requests

- Random removal
- Worst removal (remove request)
- Related removal (distance between PD requests)
- Cluster removal (related removal, few routes)
- Time-oriented removal (requests served same time)
- Historical node-pair removal (best solution obtained using edge)
- Historical request-pair removal (two requests served by same vehicle in good solution)

Repair Neighborhoods



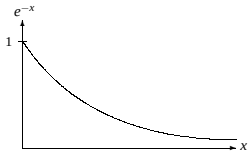
Given some partial routes, insert q requests in *parallel*

- Basic greedy heuristic
- Regret heuristics (best-second-best)

Master local search framework

Simulated annealing

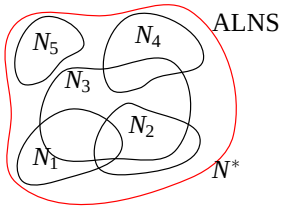
- Accept $x \rightarrow x'$ probability $e^{-\frac{f(x')-f(x)}{T}}$



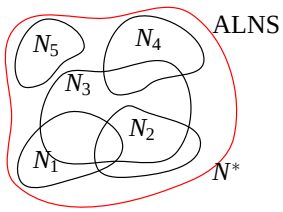
- cooling scheme $T = T \cdot c$
- automatic calibration of T_0

Noising

- Simulated annealing ensures diversification at master level
- Need diversification in destroy and repair heuristics



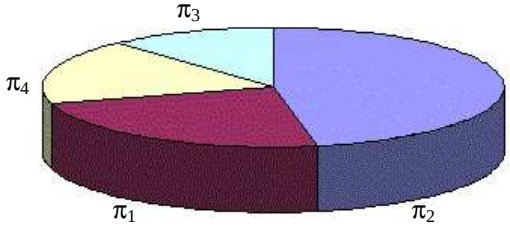
Roulette wheel selection



Each insert-remove pair is measured wrt. three criteria

- new global best solution
- new solution, improved solution value
- new solution, worse solution value

Observed score $\overline{\pi}_{i,j}$
Smoothened score $\pi_{i,j}$ weighted sum of observed and historic score



Applications of ALNS to VRP-like problems

- pickup and delivery problem with time windows (PDPTW)
- the VRP with backhauls (VRPB)
- mixed VRP with backhauls (MVRPB)
- multi-depot mixed VRP with backhauls (MDMVRPB)
- VRP with backhauls and time windows (VRPBTW)
- mixed VRP with backhauls and time windows (MVRPBTW)
- VRP with simultaneous deliveries and pickups (VRPSDP)
- VRP with time windows (VRPTW)
- capacitated VRP (CVRP)
- multi-depot VRP (MDVRP)
- site dependent VRP (SDVRP)
- open VRP (OVRP)

Rich Pickup and Delivery Problem with time windows

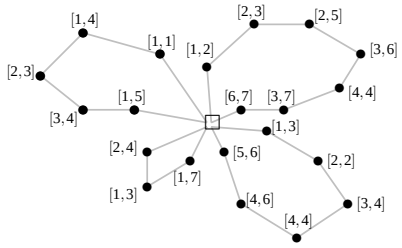
- Multiple depots
- Precedence constraints
- Site dependent
- Capacity of vehicles

Computational experiments

- Performed on 3GHz Pentium 4 computer
- Almost same parameters as in previous papers
- Up to 60 requests are removed in each iteration
- Average of 10 runs (5 if very time consuming)
- Same time limit as competing algorithms (mostly)
- Details in Tech Report Pisinger and Røpke [2005].

Compared to state-of-art algorithms when paper was submitted (2004)

VRP with Time Windows (large size)

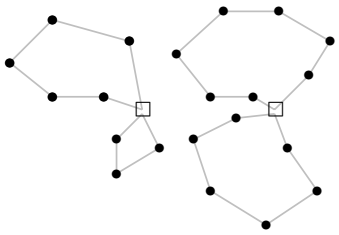


minimize: (1) vehicles, (2) distance

Gehring and Homberger [1999], 300 instances, 200-1000 customers
Gehring and Homberger [1999], Gehring and Homberger [2001], Bent and Hentenryck [2004], Bouthillier and Crainic [2004], Bräysy et al. [2003], Mester and Bräysy [2004]

- ALNS best at minimizing number of vehicles
- Improved 122/300 large-scale instances

Multi depot VRP

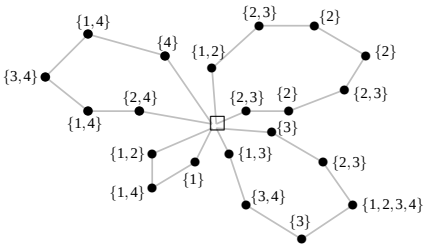


minimize: distance

Cordeau et al. [1997] (Christofides, Eilon, Gillett, Johnson, Chao)
50–360 customers
Chao et al. [1993]
Renaud et al. [1996]
Cordeau et al. [1997]

- Improved 15/33

Site dependent VRP

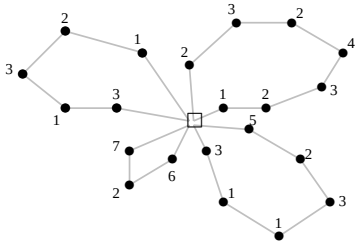


minimize: distance

Nag et al. [1988], Cordeau and Laporte [2001]
27–1008 customers
Cordeau and Laporte [2001]
Chao et al. [1999]

- Improved 30/35

Capacitated VRP

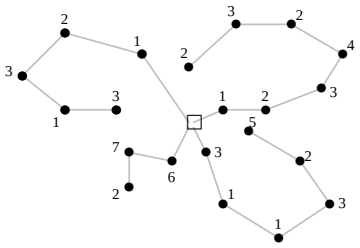


minimize: distance

Christofides et al. [1979], 50-200 customers
Golden et al. [1998], up to 483 customers
Li et al. [2004] up to 1200 customers
Toth and Vigo [2003] Li et al. [2004], Cordeau et al. [1997, 2000], Ergun et al. [2003], Prins [2004], Tarantilis and Kiranoudis [2002], Mester and Bräysy [2004], Berger and Barkaoui [2003], Reimann et al. [2004]

- cannot compete with Mester and Bräysy [2004]
- On par with remaining
- Improved 1 (Golden), 3 (Li)

Open VRP



minimize: (1) vehicles, (2) distance
route ends when last request serviced

Christofides et al. [1979], Fisher [1994] 50–199 customers
Brandão [2004] and Fu et al. [2003]

- Improved 11/16

Conclusion

General ALNS framework

- Robust wrt. size and structure of instance
- Unified solution method
- Applied to 12 variants of VRP
- Overall framework same, parameters almost same
- Improved 183/486 for VRPTW, CVRP, MDVRP, SDVRP, OVRP

Future applications of ALNS

- Branch-and-cut (cuts compete)
- Branch-and-price (pricing algorithms compete)
- Manpower planning
- Timetable problems

- Mixture of good and less good heuristics lead to better solutions than using good heuristics solely
- Necessary to hierarchically controls the search, such that well-performing heuristics are given most influence, but such that all heuristics participate to the solution process
- Obtain robust and well-performing algorithm

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