SOLVER IMPROVEMENT APPROACHES: MILES TO GO BEFORE WE SLEEP

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IMPROVEMENT HIGHLIGHTS

Measurement and Benchmarking

Code Refactor and Optimization

Heuristic Improvements

MEASUREMENT AND BENCHMARKING

QUANTIFYING SOLUTION QUALITY AND COMPUTATIONAL PERFORMANCE

MEASUREMENT AND BENCHMARKING: IDEAS

- C++ profiling and static analysis

Function / Call Stack	CPU Time ▼	Instructions Retired	Microarchitecture Usage	Module	Function (Full)
▼ LocalSearch::MergeTWDataRecursive	12.515s	93,408,000,000	81.2%	genvrp	LocalSearch::MergeTWDataRecursive(TimeWindowData const&, TimeWindowData
[No call stack information]	12.515s	93,408,000,000	81.2%		
▼ LocalSearch::MoveSingleClient	3.580s	21,852,000,000	73.7%	genvrp	LocalSearch::MoveSingleClient(void)
[No call stack information]	3.580s	21,852,000,000	73.7%		
▶ LocalSearch::run	3.255s	13,740,000,000	48.2%	genvrp	LocalSearch::run(Individual*, double, double)
▶ std::_Rb_tree_increment	3.140s	3,432,000,000	11.0%	libstdc++.so.6.0.29	std::_Rb_tree_increment(std::_Rb_tree_node_base const*)
▶ LocalSearch::MoveTwoClients	2.990s	17,400,000,000	61.6%	genvrp	LocalSearch::MoveTwoClients(void)
▶ LocalSearch::SwapTwoClientsForOne	2.975s	15,468,000,000	60.5%	genvrp	LocalSearch::SwapTwoClientsForOne(void)
▶ LocalSearch::MoveTwoClientsReversed	2.785s	18,840,000,000	71.1%	genvrp	LocalSearch::MoveTwoClientsReversed(void)
▶ LocalSearch::SwapTwoSingleClients	1.890s	8,796,000,000	59.2%	genvrp	LocalSearch::SwapTwoSingleClients(void)
▶ LocalSearch::setLocalVariablesRouteV	1.835s	11,220,000,000	54.9%	genvrp	LocalSearch::setLocalVariablesRouteV(void)
▶ LocalSearch::TwoOptBetweenTrips	1.525s	8,676,000,000	62.5%	genvrp	LocalSearch::TwoOptBetweenTrips(void)
▶ LocalSearch::setLocalVariablesRouteU	1.480s	5,820,000,000	39.9%	genvrp	LocalSearch::setLocalVariablesRouteU(void)
▶ Matrix::get	1.220s	9,228,000,000	74.5%	genvrp	Matrix::get(int, int) const
▶ Individual::brokenPairsDistance	1.180s	2,460,000,000	20.7%	genvrp	Individual::brokenPairsDistance(Individual*)
▶ LocalSearch::SwapTwoClientPairs	1.105s	7,068,000,000	64.9%	genvrp	LocalSearch::SwapTwoClientPairs(void)
▶ LocalSearch::swapStar	0.720s	2,640,000,000	36.3%	genvrp	LocalSearch::swapStar(bool)
▶ std::__detail::_Synth3way::operator()<double, double>	0.640s	348,000,000	6.0%	genvrp	std::__detail::_Synth3way::operator()<double, double>(signed char, double const&, d
▶ _int_malloc	0.540s	1,596,000,000	34.5%	libc-2.17.so	_int_malloc

MEASUREMENT AND BENCHMARKING: IDEAS

- Achieving determinism

```
void Genetic::insertUnplannedTasks(Individual* offspring, std::unordered_set<int> unplannedTasks)
{
	// Initialize some variables
	int newDistanceToInsert = INT_MAX;	// TODO:
	int newDistanceFromInsert = INT_MAX;	// TODO:
	int distanceDelta = INT_MAX;		// TODO:

	// Loop over all unplannedTasks
	for (int c : unplannedTasks)
	{
		// Get the earliest and laster possible arrival at the client
		int earliestArrival = params->cli[c].earliestArrival;
		int latestArrival = params->cli[c].latestArrival;

		int bestDistance = INT_MAX;
		std::pair<int, int> bestLocation;

		// Loop over all routes
		for (int r = 0; r < params->nbVehicles; r++)
		{
			// Go to the next route if this route is empty
			if (offspring->chromR[r].empty())
			{
				continue;
			}
```

Undefined behavior:
Loop over unordered set
Integer overflow

```
newDistanceFromInsert = params->timeCost.get(c, offspring->chromR[r][0]);
if (earliestArrival + newDistanceFromInsert < params->cli[offspring->chromR[r][0]].latestArrival)
{
	distanceDelta = params->timeCost.get(0, c) + newDistanceToInsert
		- params->timeCost.get(0, offspring->chromR[r][0]);
	if (distanceDelta < bestDistance)
	{
		bestDistance = distanceDelta;
		bestLocation = { r, 0 };
	}
}

for (int i = 1; i < static_cast<int>(offspring->chromR[r].size()); i++)
{
	newDistanceToInsert = params->timeCost.get(offspring->chromR[r][i - 1], c);
	newDistanceFromInsert = params->timeCost.get(c, offspring->chromR[r][i]);
	if (params->cli[offspring->chromR[r][i - 1]].earliestArrival + newDistanceToInsert < latestArrival
		&& earliestArrival + newDistanceFromInsert < params->cli[offspring->chromR[r][i]].latestArrival)
	{
		distanceDelta = newDistanceToInsert + newDistanceFromInsert
			- params->timeCost.get(offspring->chromR[r][i - 1], offspring->chromR[r][i]);
		if (distanceDelta < bestDistance)
		{
			bestDistance = distanceDelta;
			bestLocation = { r, i };
		}
	}
}
```

MEASUREMENT AND BENCHMARKING: IDEAS

- Achieving determinism

Undefined behavior resolved after refactor!

```
void Genetic::insertUnplannedTasks(Individual* offspring, std::unordered_set<int> unplannedTasks)
{
    // Initialize some variables
    int newDistanceToInsert = INT_MAX;     // TODO:
    int newDistanceFromInsert = INT_MAX;   // TODO:
    int distanceDelta = INT_MAX;           // TODO:

    // Loop over all unplannedTasks
    for (int c : unplannedTasks)
    {
```

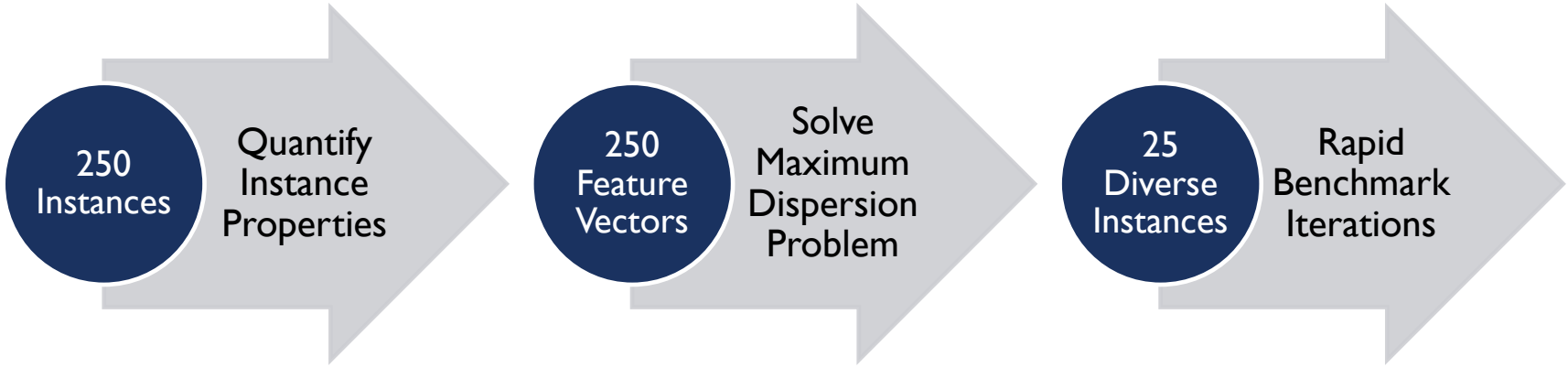
```
void Genetic::insertUnplannedTasks2(Individual* offspring, std::vector<bool> unplannedTasks)
{
    // Initialize some variables
    int newDistanceToInsert;      // Initialized for each route
    int newDistanceFromInsert;    // Initialized for each route
    int distanceDelta;            // Initialized for each route

    // Loop over all unplannedTasks
    int c=0;
    for (bool b : unplannedTasks)
    {
        if(!b){
            c++;
            continue;
        }
```

```
        for (int i = 1; i < static_cast<int>(offspring->chromR[r].size()); i++)
        {
            newDistanceToInsert = params->timeCost.get(offspring->chromR[r][i - 1], c);
            newDistanceFromInsert = params->timeCost.get(c, offspring->chromR[r][i]);
            if (params->cli[offspring->chromR[r][i - 1]].earliestArrival + newDistanceToInsert < latestArrival
                && earliestArrival + newDistanceFromInsert < params->cli[offspring->chromR[r][i]].latestArrival)
            {
                distanceDelta = newDistanceToInsert + newDistanceFromInsert
                    - params->timeCost.get(offspring->chromR[r][i - 1], offspring->chromR[r][i]);
                if (distanceDelta < bestDistance)
                {
                    bestDistance = distanceDelta;
                    bestLocation = { r, i };
                }
            }
        }
```

```
        for (int i = 0; i <= static_cast<int>(offspring->chromR[r].size()); i++)
        {
            int previousOnRoute = (i == 0) ? 0 : offspring->chromR[r][i - 1];
            int currentOnRoute = (i == static_cast<int>(offspring->chromR[r].size())) ? 0 : offspring->chromR[r][i];
            newDistanceToInsert = params->timeCost.get(previousOnRoute, c);
            newDistanceFromInsert = params->timeCost.get(c, currentOnRoute);
            if (params->cli[previousOnRoute].earliestArrival + newDistanceToInsert < latestArrival
                && earliestArrival + newDistanceFromInsert < params->cli[currentOnRoute].latestArrival)
            {
                distanceDelta = newDistanceToInsert + newDistanceFromInsert
                    - params->timeCost.get(previousOnRoute, currentOnRoute);
                if (distanceDelta < bestDistance)
                {
                    bestDistance = distanceDelta;
                    bestLocation = { r, i };
                }
            }
        }
```

MEASUREMENT AND BENCHMARKING: IDEAS

- Representative subsets of benchmark instances



Feature set:

- dimension
- capacity
- demandMeanOverCapacity
- distanceToDepotCV
- demandCV
- timeWindowCV
- serviceCV

CODE REFACTOR AND OPTIMIZATION

ROAD TO STATIC SCORE IMPROVEMENT: SPEED THINGS UP WHEREVER POSSIBLE

CODE REFACTOR AND OPTIMIZATION: IDEAS

- Avoid recursions and force inline execution of simple functions
- Rewrite Matrix class to speed up Matrix::get(), which is called all over the place
- Swap out data structures and sort algorithms for more efficient ones

CODE REFACTOR AND OPTIMIZATION: IDEAS

- Avoid recursions and force inline execution of simple functions
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- **Swap out data structures and sort algorithms for more efficient ones**

```
57  -         std::multiset<std::pair<double, Individual*>> indivsPerProximity;
      // The other individuals in the population (can not be the depot 0), ordered by
      increasing proximity (the set container follows a natural ordering based on the
      value of the first pair)
```

```
58  +         std::multiset<double> proximities;                    // The proximities
      of other individuals in the population (can not be the depot 0), ordered by
      increasing proximity (the set container follows a natural ordering based on the
      value of the first pair)
59  +         std::unordered_map<Individual*,double> proximityPerIndividual;
```

CODE REFACTOR AND OPTIMIZATION: IDEAS

- Avoid recursions and force inline execution of simple functions
- Rewrite Matrix class to speed up Matrix::get(), which is called all over the place
- **Swap out data structures and sort algorithms for more efficient ones**

16 baselines/hgs_vrptw/Individual.cpp

```
@@ -115,15 +115,7 @@ void Individual::shuffleChromT()
```

```
115
116  void Individual::removeProximity(Individual* indiv)
117  {
118 -        // Get the first individual in indivsPerProximity
119 -        auto it = indivsPerProximity.begin();
120 -        // Loop over all individuals in indivsPerProximity until indiv is found
121 -        while (it->second != indiv)
122 -        {
123 -                ++it;
124 -        }
125 -        // Remove indiv from indivsPerProximity
126 -        indivsPerProximity.erase(it);
127  }
```

```
115
116  void Individual::removeProximity(Individual* indiv)
117  {
118 +        proximities.erase(proximityPerIndividual[indiv]);
119  }
```

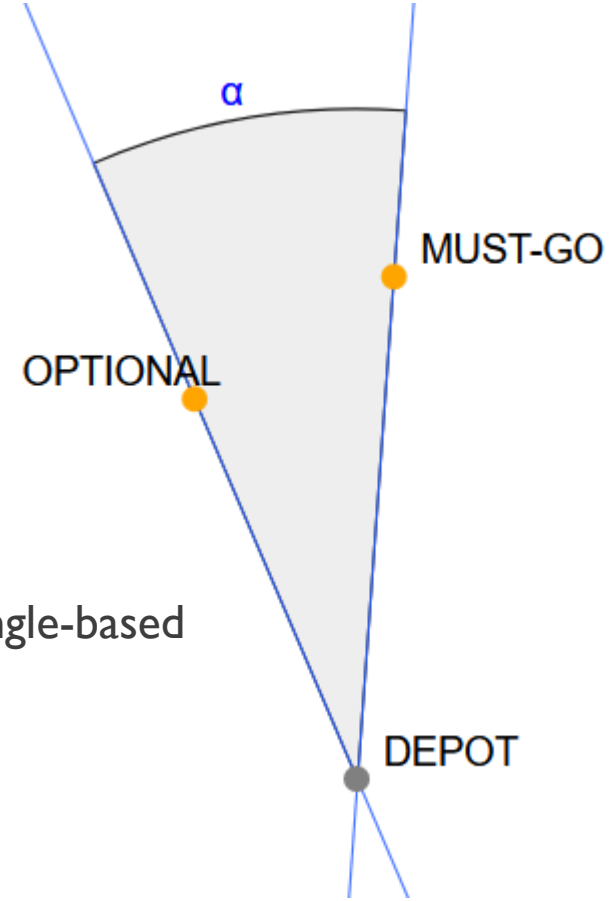
HEURISTIC IMPROVEMENTS

SIMPLE STRIDES TOWARD A BETTER DYNAMIC SOLVER

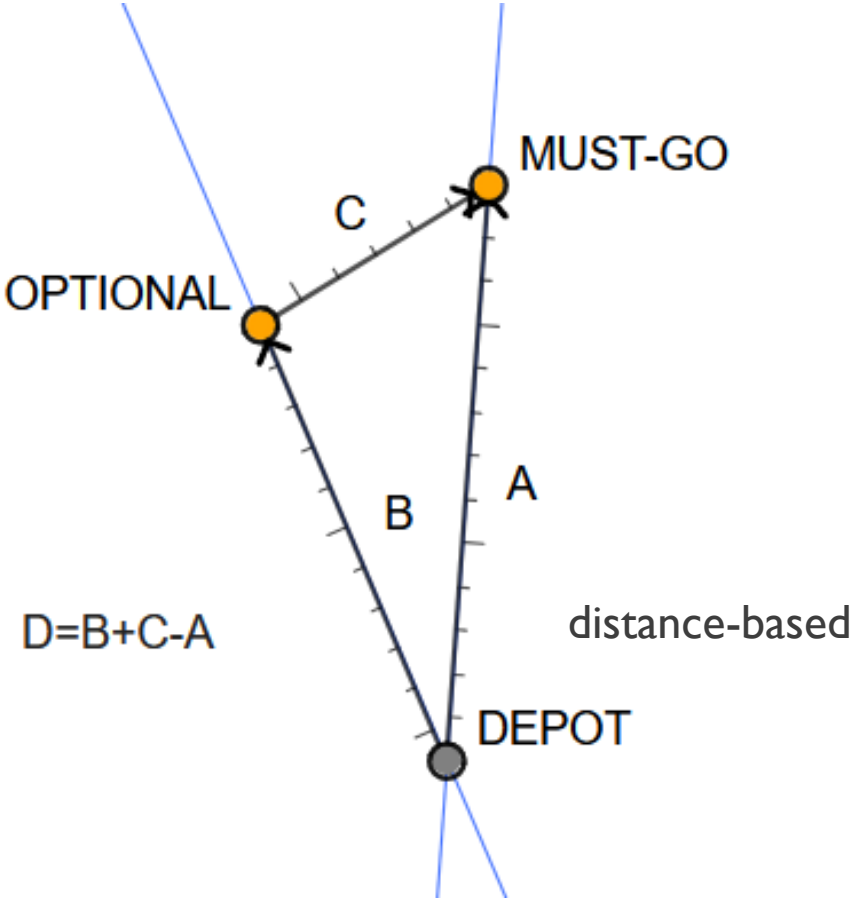
HEURISTIC IMPROVEMENTS: IDEAS

- Postprocess: if a route contains 100% optional clients, postpone them all
- Preprocess: mark only a subset of optional clients for potential dispatch
  - choose this subset by ranking all clients via one of two simple heuristics, then:
    - select all clients with heuristic score less than a fixed parameter OR
    - select a percentage of all optional clients with smallest heuristic scores, based on a fixed parameter OR
    - select up to the N optional clients with smallest heuristic scores, where N is a multiple of the number of must-go clients

HEURISTIC IMPROVEMENTS: IDEAS



angle-based



distance-based

The two heuristics

Github:
https://github.com/steveharenberg/sas-euro-neurips-vrp-2022.git

THANK YOU