Approximation of point equilibria in MATSim

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Two MATSim contribs accompanying the hEART 2023 presentation "Improved precision in a heuristic for particle-based and stochastic dynamic traffic assignment" are presented. The underlying heuristic approximates point equilibria, i.e. reproducible "relaxed" states with minimal randomness in simulation setups that comprise the iterative "mobsim/scoring/replanning" logic of MATSim. An (already somewhat outdated) implementation of the method is on https://github.com/gunnarfloetteroed, it will be replaced with the version presented at hEART 2023 by the time of the conference.

The assignment method relies on the (approximate) minimization of an *equilibrium gap* that measures, for every agent, how much that agent could improve its score by changing its plan if all other agents kept their plans. The gap is always non-negative and zero at a (possibly non-existing) Nash equilibrium. The assignment method aims to reduce the gap in subsequent MATSim iterations, steering the simulation process towards a state that has a low gap, and hence may be deemed to be near an equilibrium point.

Apart from computing reproducible low-variability results, this approach provides a clear statement of what the simulation attempts to achieve when iterating the "MATSim loop". This may help to argue more convincingly in favor of an agent-based approach rather than a traditional four-step/static-assignment model system: The single most important advantage of the latter is its ability to reproducibly compute point equilibria.

The method is encoded in two contribs.

The emulation contrib is a successor of the ier (iterative emulated replanning) contrib, which in turn succeeds the psim (pseudo simulation) contrib. All of these execute MATSim plans in a simplified mobility simulation where all movement-related performance measures are fixed (including exogeneously set travel times). This allows to evalute new plans in (possibly hypothetical) network conditions in a computationally efficient manner, prior to their computationally more involved execution in the mobility simulation. This capability is central for computing the aforementioned equilibrium gap, in that it allows an agent to myopically optimize its travel plan in an otherwise unchanged physical world. (We also use it in the simulation-based optimization of vehicle sharing stations, where it allows to anticipate demand responses without permanently re-running the simulation with new station configurations.) Specifications of new transport modes can be rather straightforwardly injected into the emulation contrib.

The greedo contrib depends on the emulation contrib and turns the MATSim loop into a point equilibrium approximation procedure. Plugging this contrib into MATSim requires minimally three lines of code:

```
Greedo greedo = new Greedo();
...
Config config = ...;
greedo.meet(config);
...
Controler controler = ...;
greedo.meet(controler);
...
controler.run();
```

The method is illustrated in a multi-modal Greater Stockholm scenario that, in its maximal setup, comprises all-day choice of route, departure time, and mode. A unimodal car-only version is used to benchmark the method in a more conventional setup.