Fundamentals of Traffic Operations and Control
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Exercise
Perimeter control
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Consider a two-region urban network with regions denoted by R1 and R2, and four different types of demand flow $q_{11}(t)$, $q_{12}(t)$, $q_{21}(t)$, and $q_{22}(t)$ as shown in Figure 1. The variables $u_{12}(t)$ and $u_{21}(t)$ are the perimeter control variables, which restrict the flow from R1 to R2, and from R2 to R1 respectively [1]. The purpose of this exercise is to investigate the performance of a PI controller which, by comparing the difference between the measured traffic accumulation and reference accumulation, determines the control actions u_{12} and u_{21}. In the given problem settings, we implement two PI controllers, one for every control action. The PI controller for the control variable u_{12} compares the accumulation in R1 that we denote by n_1 with an exogenously defined reference value n_1^{ref}. In a similar manner, u_{21} compares the accumulation in R2 that we denote by n_2 with a given reference value n_2^{ref}. Finally, we compute the Passenger Hour Travelled (PHT) inside the two regions and use this metric to evaluate and compare the performance of the controllers under different network settings.

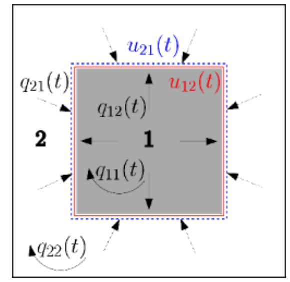

Figure 1: Two-region network flow

For the purpose of this exercise, please refer to the simulation code *"MFD_PC_Sim_TwoRegions.m"* provided to you and follow the instructions in the command window. The states and control inputs are plotted at each control step while the values of PHT are displayed at the end of the simulation. For problems a, b, and c, you will be prompted to define the reference accumulation for R1 and/or R2. Moreover, you will have to input the demand scaling factor α responsible for scaling down or up the nominal demand values.

a) Given a PI controller for R1 only (city center), test the effect of the reference point n_1^{ref}, and compare the PHT in the sub-regions as well as in the total network for the values

   - $n_1^{ref} = 3400$ [veh],
   - $n_1^{ref} = 3060$ [veh],
   - and test other values for n_1^{ref}.

   Investigate the performance for different demand scaling factors $\alpha \in [0.5, 2]$ and comment on the results.

b) Given a PI controller for R1 and R2, test the effect of the reference points n_1^{ref} and n_2^{ref} with $n_1^{ref} = n_2^{ref}$, and compare the PHT in the sub-regions as well as in the total network for the values

   - $n_1^{ref} = n_2^{ref} = 3060$ [veh],
   - $n_1^{ref} = n_2^{ref} = 3400$ [veh],
   - and test other values for n_1^{ref} and n_2^{ref}.

Investigate the performance for different demand scaling factors $\alpha \in [0.5, 2]$ and comment on the results.

c) Given a PI controller for R1 and R2, test the effect of the reference points n_1^{ref} and n_2^{ref}, and compare the PHT in the sub-regions as well as in the total network for the values

- $n_1^{ref} = 3060$ [veh], $n_2^{ref} = 3400$ [veh],
- $n_1^{ref} = 3400$ [veh], $n_2^{ref} = 3060$ [veh],
- and test other values for n_1^{ref} and n_2^{ref}.

Investigate the performance for different demand scaling factors $\alpha \in [0.5, 2]$ and comment on the results.

d) Given the results you obtained, what are the pros and cons of using a perimeter control approach to mitigate congestion in urban networks? Moreover, list one advantage for using two PI controllers for both R1 and R2 instead of a single PI controller for R1/R2.

References

[1] Nikolas Geroliminis, Jack Haddad, and Mohsen Ramezani. Optimal perimeter control for two urban regions with macroscopic fundamental diagrams: A model predictive approach. *IEEE Transactions on Intelligent Transportation Systems*, 14(1):348–359, 2013. doi: 10.1109/TITS.2012.2216877.