Quantitative Analysis of Systems (QAS)

Academic Year 2020-2021
*Project on **Modeling and Evaluation***

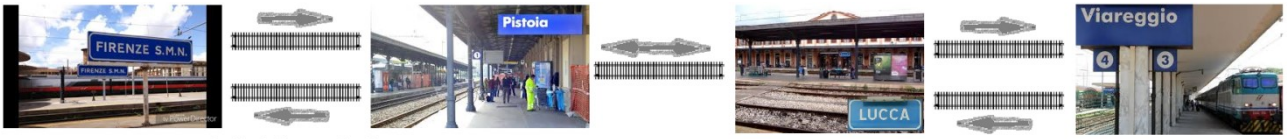
Performance analysis of a Railway line

The project aims to model and evaluate the performances of a railway line. Info on the expected content of the project and on how to submit it is detailed in the "Project Submission" session at the end of this document.

In the following we present the details of the project to clarify the objective. The project requires a modeling and evaluation exercise, using an appropriate modeling formalism, aimed at characterizing the performances of a railway line between the cities of Florence and Viareggio (terminals).

The line is divided into 3 sections:

- Section n. 1 from Florence and Pistoia, with double track (one track for each traveling direction);
- Section n. 2 from Pistoia and Lucca, with single track (one track only, shared by the two traveling directions);
- Section n. 3 from Lucca and Viareggio, with double track (one track for each traveling direction).



Section 1: Florence - Pistoia *Section 2: Pistoia - Lucca* *Section 3: Lucca - Viareggio*

The line has a total of *N* trains, and each train has only one available locomotive. Initially there will be *N* / 2 trains in the Florence station, and *N* / 2 trains in the Viareggio station.

- Trains depart from each terminal (Florence and Viareggio). Each track on each section can be occupied by one train at a time. A train can only depart from a station if there are no trains on the track it must occupy; otherwise the train stops at the station until the track is free.
- Florence and Viareggio stations do not have any constraint on the number of trains they can host (infinite platforms), while Pistoia and Lucca stations can host no more than *P+1* and *L+1* trains, respectively.
- When in the station of Pistoia there are *P* (or more) trains waiting to depart (directed to Florence or Lucca), then the trains ready to depart from the station of Florence towards Pistoia are blocked until the number of trains in the Pistoia station becomes lower than *P*. Train already departed from Florence or Lucca can anyway reach Pistoia.
- When in the station of Lucca there are *L* trains (or more) waiting to depart (towards Viareggio or Pistoia), then the trains ready to depart from the station of Viareggio towards Lucca are blocked until the number of trains in the Lucca station becomes lower than *L*. Train already departed from Viareggio to Pistoia can anyway reach Lucca.

- When there are trains both in Lucca and Pistoia ready to enter in Section 2 and occupy the shared single track connecting the two stations, then the access permission is granted by the adoption of one of the following contention policies:
    - Contention policy 1 (alternation): alternate the departures of the trains in the two directions (starting from Pistoia), i.e., the first time of contention the access permission is granted to a train in Pistoia directed to Lucca, then the next time it is granted to a train in Lucca directed to Pistoia, and so on.
    - Contention policy 2 (Pistoia first): always give the precedence to the trains in Pistoia directed to Lucca.
    - Contention policy 3 (Lucca first): always give the precedence to the trains in Lucca directed to Pistoia.
- When a train reaches one of the terminals (Florence or Viareggio) it is cleaned, and then it is ready to depart again in the opposite direction. The cleaning service has an exponential duration with mean of 30 minutes.
- The travel times, for each section, are exponentially distributed with a mean equal to:
    - 30 minutes for Section 1,
    - 40 minutes for Section 2,
    - 50 minutes for Section 3.
- Along each section, a train can stop due to a locomotive fault with a probability *h*, and in this case it will resume again its trip after an exponential time with a mean of 90 minutes.

Considering an increasing number of *N* trains (*N*=2, 6, 10, 14, 18, 22) and the adoption of the three contention policies (alternation, Pistoia first, Lucca first), perform the following analyses:

- Analysis 1: compute the mean number of trains waiting in the stations of Florence, Pistoia, Lucca and Viareggio at time t=1, 6, 12, 24, 48, 96, 192, 384 hours and at steady-state, at varying of *N* and for the different contention policies. For the other parameters, use the following setting: *P*=4, *L*=6, *h*=0.001.
- Analysis 2: compute the mean number of trains that have completed a travel from one terminal to the other terminal in the first t=1, 6, 12, 24, 48, 96, 192, 384 hours, at varying of *N* and for the different contention policies. For the other parameters, use the following setting: *P*=4, *L*=6, *h*=0.001.
- Analysis 3: fixing one value for *N*, and fixing one specific contention policy, find the minimum values for P and L that maximizes the mean number of trains that have completed a travel from one terminal to the other terminal in the first 384 hours. For the other parameters, use the following setting: *h*=0.001.
- Analysis 4: Using the same setting of the parameters adopted for Analysis 3 concerning *N* and the contention policy, and using the minimum values for *P* and *L* find in Analysis 3, compute the mean number of trains that have completed a travel from one terminal to the other terminal in the first t=1, 6, 12, 24, 48, 96, 192, 384 hours, at varying of the parameter *h* = 0.00001, 0.0001, 0.001, 0.01, 0.1.

NOTE: Missing system specifications (if any) should be identified and properly addressed, e.g. introducing proper modeling assumptions.

Project Submission:

The project can be developed **individually** or by a group of students (**3 students max per group**).
The result of the project consists of a written report and the implemented models.

The written report must be in PDF format and must have the following minimum content:

- Name, surname and serial number of the student (or of the students forming the group).
- Analysis of the problem (the addressed problem, how it has been solved, what are the introduced assumptions).
- Synthetic (high level) description of the behavior captured by the atomic (and composed, if implemented) models, aimed at convincing an external reader that the models properly solve the problem without forcing him to analyze all the technical details of the models.
- Detailed description of the models. All the information required to understand the behavior of the models must be reported. At a minimum, students have to specify:
    - atomic models (with the figures),
    - composed model (if existing),
    - initial marking,
    - probability and time distributions,
    - enabling conditions,
    - marking change operations (e.g., code of input/output gates),
    - global variables,
    - places shared between the models (if they exist).
- Definition of reward variables (important - in detail).
- Parameters' values used for the study.
- Used solver, with indication of the main parameters. For example, in the case of Mobius, specify whether you use the Mobius simulator (Mobius Simulator) or an analytical solver (Transient Solver, Accumulated Reward Solver, Direct Steady State Solver, etc.). Guidelines on how to properly select the analytical solver can be found at: https://www.mobius.illinois.edu/wiki/index.php/Numerical_Solvers. In the case of the Mobius Simulator, specify whether you are performing a Terminating Analysis or a Steady-State Analysis. In the case of Steady-State Analysis it is necessary to specify the initial transient, the batch size, the minimum and maximum number of batches, etc.
- Results obtained from the solver, shown in textual form (table, sequence of numbers) or, better, using figures and graphs, with comments that explain and justify the trend of the obtained results (important!).
- Conclusion, highlighting what has been learned from the analysis of the project results.

The model developed with a tool must be compressed and stored in a single file (possibly tar.gz). In the case of Mobius, use the archive command provided by the tool, which generates a file of format tar.gz.

A single tar.gz format file named "QAS-assignment-xyz.tar.gz", where x, y, and z are the initials of name and surname of each of the members of the group, should be sent to Lollini and Zoppi (paolo.lollini@unifi.it, tommaso.zoppi@unifi.it) containing only TWO files:

- a PDF file for the report;
- a tar.gz file containing the developed models.

Note that **each group may submit the final version of their project at any time**. Once accepted, the professors will agree with the students on a date for the oral interviews (usually within 1 week). All the members of each group will be interviewed in the same day. The exam, if passed, will be officially registered at the next formal session (appello) available for the course.