Using SMARTS as a Standalone Program, Version 1.1

SMARTS can run as a standalone program or a distributed system. This document details the standalone program, smarts.jar. As the standalone program runs within a single JVM, it can be a good choice for performing small-scale simulations. The standalone program shows a GUI when it is launched. Users can control and monitor simulations with the GUI. Closing the GUI exits the program.

The GUI consists of two panels. The left one is **Monitor Panel**, which visualizes simulations. The right one is **Control Panel**, which is for controlling simulations. The control panel consists of several sections, which can be folded or opened by clicking the section titles.

If you are new to the simulator, you may want to try a simulation with all the parameters at their default values. Simply click the **Run Simulation** button to start a quick demo simulation.

You can move the road map or zoom it with the widgets on the monitor panel or with certain mouse operations. To move the map with mouse, hold down the right mouse button and drag the map. To zoom the map, you can either use mouse wheel or double click the map. Double-click with left mouse button can zoom in. Double-click with right mouse button can zoom out.

At the default zoom level, vehicles are drawn as coloured points. The colour of a vehicle point depends on the vehicle's speed relative to the free-flow speed, i.e., speed limit of road. The speed of red vehicles is significantly lower than the free-flow speed. The speed of green vehicles is close to the free-flow speed. The speed of other vehicles is in between.

When you move mouse over the map, you will see the highlighted road edge at the mouse pointer. Details about the edge will be shown at the edge in the following order, street name (is there is one), number of lanes, length, start/end node ID, index of the edge in the road network, speed limit of the edge. Note that any edge has a start node and an end node. To differentiate the two nodes, the start node is drawn with a square. For two-way roads, where there are two edges overlap with each other, you will see the change of start node and end node as you move mouse over the edge.

The simulation can be paused or stopped by clicking the associated buttons on the control panel.

Section 1: Simulation Setup

The control panel contains three sections related to simulation setup.

The first section is **computing resource**. SMARTS consists of one **server** component and one or more **worker** components. In the centralized version of the simulator, the server and all the workers share one JVM. Depending on the scale of road map and the hardware of your computer, using multiple workers in the centralized simulation system may help speed up simulations. For example, if you run the simulator with a multi-threaded CPU, a large amount of memory and a relatively small road map, using multiple workers may achieve a higher speedup than using a single worker.

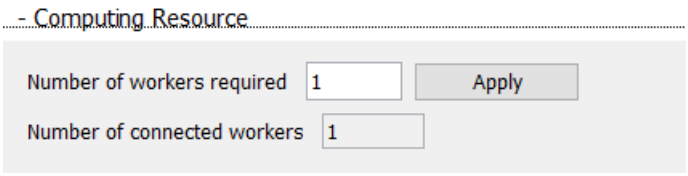
The second section is **map**. You can load OpenStreetMap data or download the data within the simulator. SMARTS builds road networks based on the data.

The third section is **miscellaneous settings**, which include input, output, model parameters and other settings.

Besides the options on control panel, you can also config certain parameters on the monitor panel.

The rest of this section details the setup options that are available from different parts of the GUI.

1.1 Computing Resource



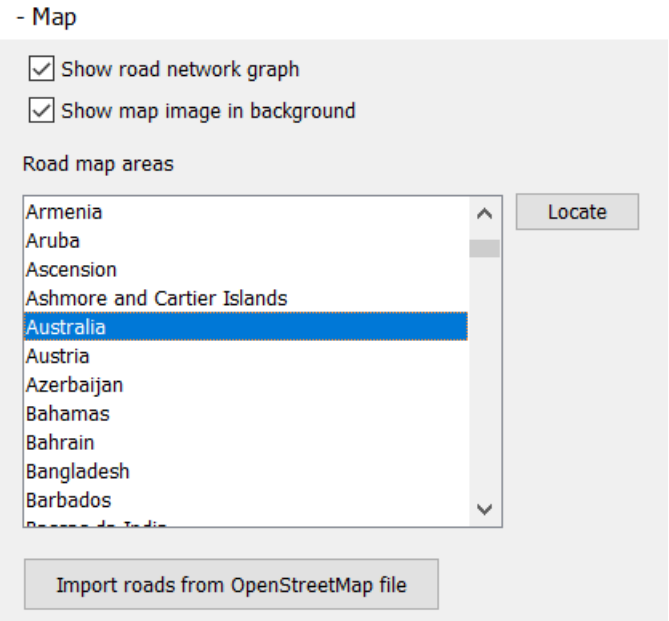
By default, there is only one worker when the simulator starts. To change the number of workers, input the new number in **Number of workers required** field then click **Apply** button. SMARTS will build the workers and connect them with the server.

1.2 Map

You can check the **Show map image in background** option. Once the option is checked, static map image from Google Map will be displayed on the monitor panel. Please note that this option has been changed to "Show place names from GeoNames.org" from Jan 2020 as OpenStreetMap imposed some limitations of accessing map images from their servers.

To load an OpenStreetMap XML data file, simply click **Import roads from OpenStreetMap file** button and follow the prompts. The data file should already exist on the disk. The file may be an original

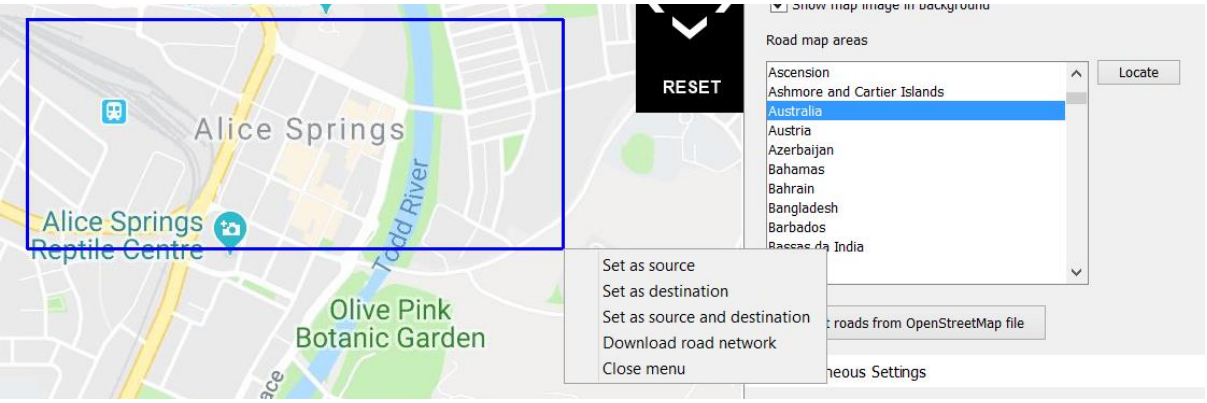
OpenStreetMap data file downloaded to the disk. It may also be a customized data file in OSM XML format. You can use third-party tools, e.g., JOSM, to create or edit an OSM file and load it into SMARTS.



The simulator provides a convenient way to download OpenStreetMap data. To help users find the area of interest, SMARTS provides shortcuts to the centre points of a number of territories. You can scroll the **Road map areas** list to find a territory around the world. Once the territory name is highlighted, you can click the **Locate** button to align the map centre with the centre of the territory. After that, you can move and zoom the map until you find the area of interest.

One the area of interest is shown on monitor panel, you need to specify a rectangular area by dragging mouse while holding down the left mouse button on the monitor panel. The highlighted area is shown as a blue rectangle. Once the area is defined, you can select the **Download road network** option from a popup menu. Once the downloading is completed, you can choose to set up a simulation with the downloaded data. The downloaded data is saved to **download.osm**. Please note that the file will be rewritten each time you download data. The downloading can take quite a bit of time, depending on the complexity and the size of the map. SMARTS shows the progress of downloading until the data is fully downloaded.

The following screenshot shows an example, where Australia is selected from the road map areas. An area in Alice Springs, a town in the middle of Australia, is highlighted. The popup menu, which shows the option for downloading data, is displayed alongside the highlighted area.



1.3 Miscellaneous Settings

Foreground and **background** are two key terms that are used in this section. If a vehicle is at foreground, it is possible to output the vehicle's trajectory and travel time when it reaches its destination. If a vehicle is at background, it is possible to output the vehicle's initial route plan.

The details of the settings are as follows.

Foreground route file You can load a file containing the route plan of foreground vehicles. To do this, click the Change button and follow the prompts. The path of the selected route file will be shown.

Background route file This is similar to the previous setting except that the route file is for background vehicles.

Number of random private vehicles This is the number of non-public vehicles that are randomly generated by the simulator internally. SMARTS will try to maintain the specified number of vehicles during a simulation. Note that any randomly generated vehicle is a background vehicle.

Number of random trams (if applicable) This is similar to the previous setting except that the number is for trams. Note that this setting has no effect if the OpenStreetMap data, from which the road map is built, does not contain any tram route. SMARTS will try to maintain the specified number of trams if it was possible.

Number of random buses (if applicable) This is similar to the previous setting except that the number is for buses. SMARTS will try to maintain the specified number of buses if it was possible.

Max number of steps The simulation will automatically stop when the maximum number of steps is reached.

Number of steps per second This setting determines the step length. For example, if there are 5 steps per second, the simulation progresses with 0.2 second step length. That means a vehicle, which is travelling at 10 metres per second, moves 2 metres at each time step. If the number of steps per second increases to 10, the vehicle moves 1 metre at each time step. A high number of steps per second can result in a smooth but slow progression of traffic.

Look-ahead distance in metres This controls the distance, within which a vehicle looks for traffic lights, front vehicles, conflict traffic at intersection, etc. For realistic simulation, this distance should not be too small, e.g., 1 metre.

Traffic light timing There are three options. Fixed timing means the length of colour phases never changes. Dynamic timing means a street can be granted green light indefinitely if there was no incoming traffic from conflicting streets. If there was incoming conflict traffic, the system will try to grant green light to the conflicting traffic sooner. None means the traffic lights are disabled during a simulation.

Routing algorithm for new routes The algorithms are used for generating routes of random private vehicles. The current version includes two options. **Dijkstra** is the classic Dijkstra's algorithm. **RandomAStar** is a variation of A* algorithm, where routes are more diversified than in the original A* algorithm. Note that the selected routing algorithm will also be used for re-routing of private vehicles.

Server-based synchronization When a simulation is server-based, all the workers must report to server at each time step. The server instructs all the workers what to do next at each step. On the contrary, in serverless mode, where the server is not involved in synchronization, the workers do not need to be instructed by the server at each time step. The workers only report the simulated traffic to server at a certain interval. Generally, simulations can run faster in serverless mode. However, the workers may not be able to respond to users' input immediately as in server-based mode during a simulation.

Output initial route of random vehicles If this option is selected, the initial routes of internally generated random vehicles will be saved to a file on the disk. Note that the initial routes may be different to the actual routes if the option allowing re-route is enabled.

Output travel time of foreground vehicles If enabled, the travel time of foreground vehicles, which have reached their destinations, will be saved to a file on the disk.

Output simulation log Some general information about completed simulations, such as simulation time, will be saved to a file on the disk.

Output trajectory of foreground vehicles The time-stamped positions of foreground vehicles, which have reached their destinations, will be saved to a file if this option is enabled. Importantly, a trajectory does not necessarily follow the initial route if rerouting was enabled.

Allow vehicles change route If this option is enabled, vehicles can reroute in certain circumstances, such as being stuck in traffic congestion for too long. Re-route can happen to all vehicles.

1.4 Monitor Panel

As mentioned in Section 1.2, you can choose options from a popup menu after you define a window on monitor panel. The popup menu provides the following options.

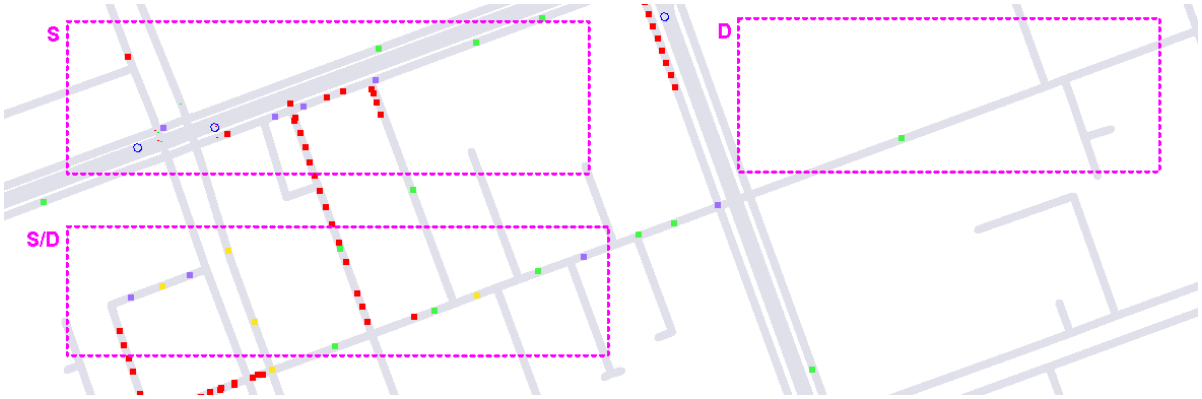
Set as source The highlighted rectangular area will be used as an area, where the source of random vehicle routes will be created. The window will be marked with **S** once you choose this option from the popup menu. Note that you can define an arbitrary number of source windows. These windows can overlap with each other. If there is one or more source windows, the random vehicles will only start from the source windows. Otherwise, the sources of random vehicles are uniformly distributed around the road network. Note that there are certain restrictions on the edges, where random vehicle routes can start. For example, a car cannot start from a tram track. You may need to look at the source code for the restrictions.

Set as destination Similar to the above but the window is for destination of vehicles. The window will be marked with **D**.

Set as source and destination Similar to the above but the window is for both sources and destination. The window will be marked with **S/D**.

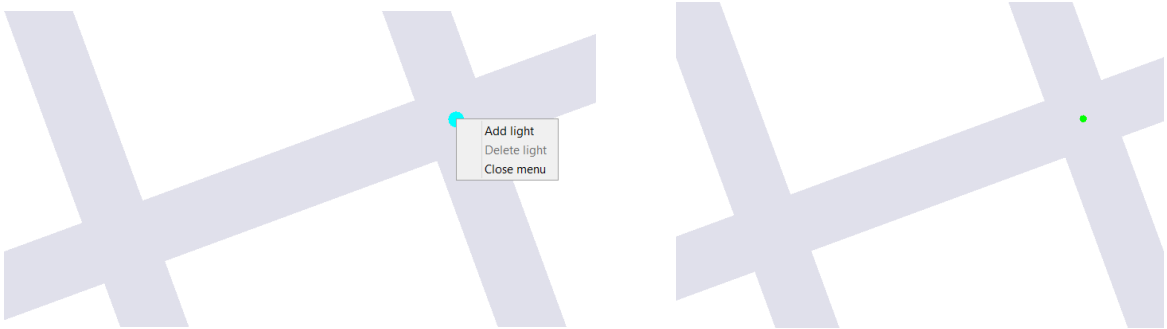
You can remove an existing window. To do this, move mouse over an edge of the window until the window is highlighted. Click left mouse button to pop up a menu. Then remove the window by selecting the associated option.

The following screenshot shows a simulation with three windows. The top left window is a source window. The top right one is a destination window. The bottom left one is a source and destination window. All the vehicles that start from the top-left window will reach the top-right window or the bottom-left window. Some of the vehicles that start from the bottom-left window will end trips in the same window while others will reach the top-right window.



You can also add or remove traffic lights at intersections during setup. In the following example, we remove a traffic light from the left intersection and create one at the right intersection.

Step 1: Move mouse over the left intersection until the intersection is highlighted. Click the intersection to open a popup menu. The left screenshot shows the popup menu at the highlighted intersection. Select **Delete light** from the popup menu. The right screenshot shows the area after the traffic light is removed.



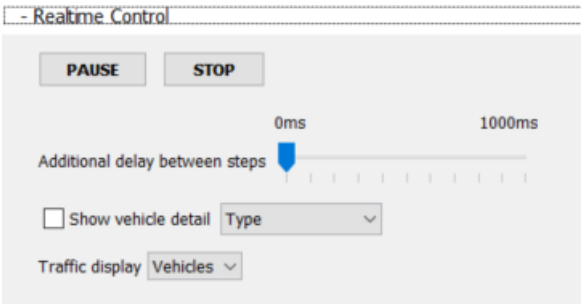
Step 2: Move mouse over the right intersection until the intersection is highlighted. Click the intersection to open a popup menu. The left screenshot shows the popup menu at the highlighted intersection. Select **Add light** from the menu. The right screenshot shows the area after the traffic light is added.

Section 2: Controlling Simulation at Real Time

This section details the real time controls that are available from different parts of the GUI.

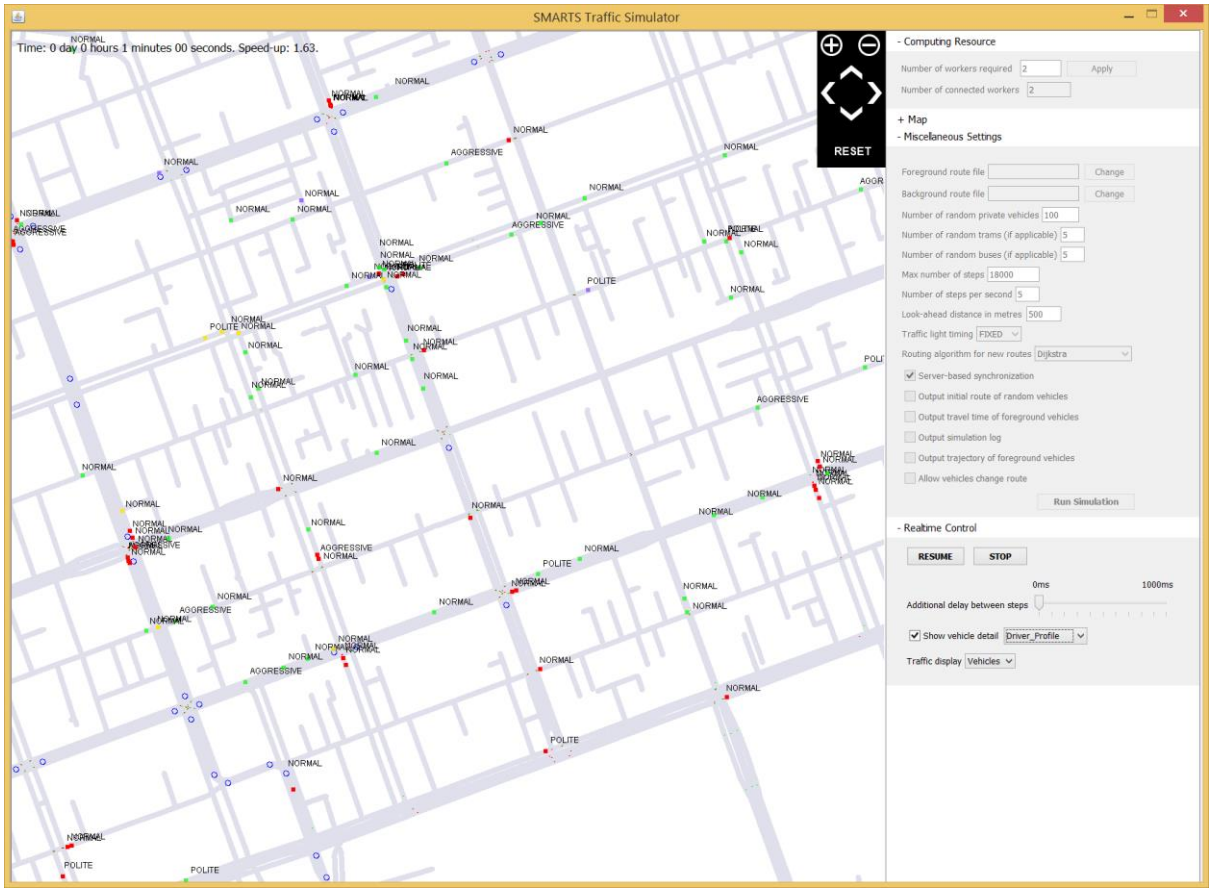
2.1 Realtime Control Panel

The control panel section, **Realtime Control**, is enabled once a simulation is started.



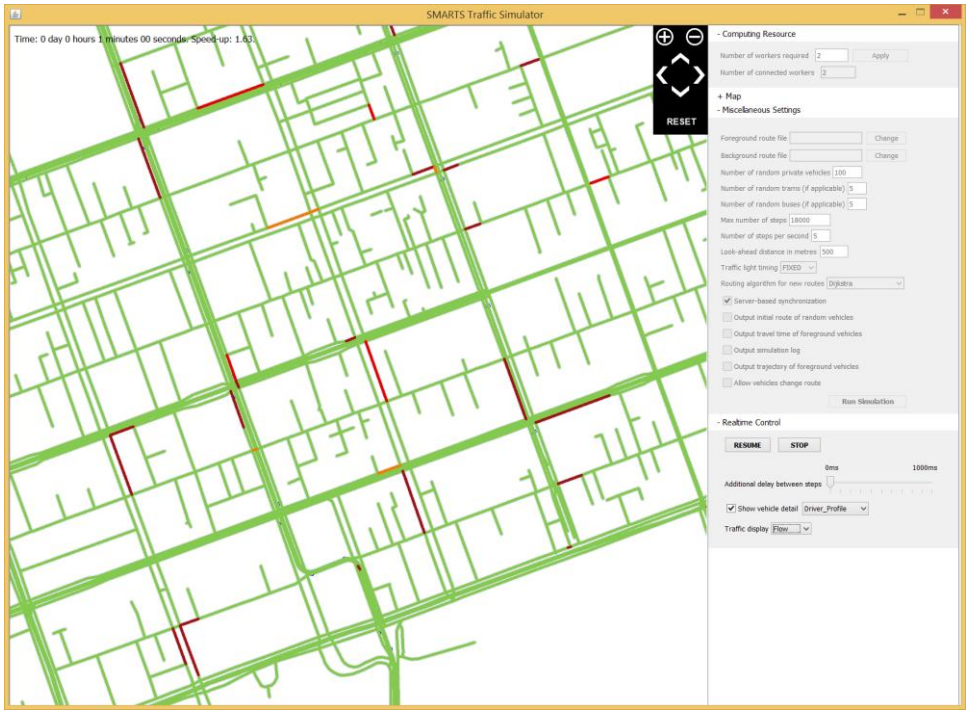
You can add an additional delay between steps. By default, there is no additional delay, which means the system starts simulating the next time step as soon as the traffic at the current step is simulated. If there is an additional delay, the system waits for a specific period when the current step is simulated. An additional delay may help you examine the change of traffic between adjacent steps.

If the **Show vehicle detail option** is checked, a tag will be displayed with any vehicle. The tag can show one of the following details. (1) **Type**: Vehicle type, e.g., car, bus, etc. (2) **Remaining_Links**: The number of remaining edges that a vehicle needs to go through before reaching its destination. (3) **ID_Worker**: The vehicle's ID and the ID of the worker, which is simulating the vehicle. For example,



ABCD35@WXYZ means vehicle ABCD35 is running on worker WXYZ. (4) **Driver_Profile**: The profile controlling the aggressiveness of driving.

By default, individual vehicles are shown on the monitor panel during a simulation. You can switch the traffic display mode between Vehicles and Flow. In Flow mode, the colour of road edges indicates the average vehicle speed associated with the edge. If the colour of an edge is red, vehicles are moving slowly on the edge. The following screenshot shows an example where traffic flow is visualized.

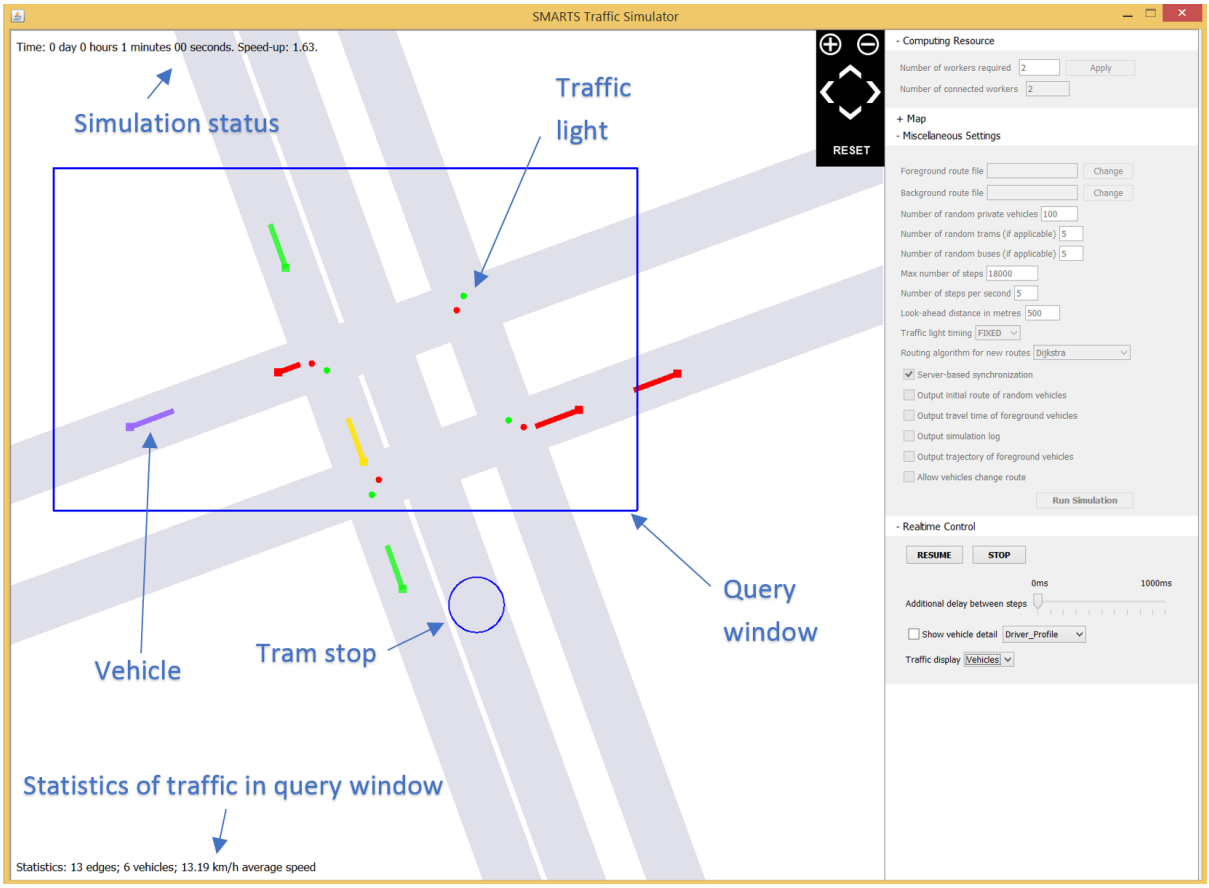


2.2 Monitor Panel

The monitor panel shows various information.

The status of the simulation is shown in the top-left corner of the monitor panel. The status includes the real time of simulation and the speed-up value. The speed-up value depends on the actual time used for simulating traffic (simulation time) and the real time. For example, if it took 1 second to simulate 5-seconds traffic, the speed-up is 5. Note that the speed-up may not be accurate if you specify additional delay between time steps (Section 2.1).

You can define a query window on monitor panel, i.e., the blue rectangular shown in the following screenshot, during a simulation. Statistics of the traffic in the window will display in the bottom-left corner of the panel.



You can also block and unlock specific traffic lanes during a simulation. To do this, move mouse pointer over an edge until the edge is highlighted. (For an edge on a two-way road, which has two overlapping edges in opposite directions, make sure the correct edge is selected.) An edge has one or more lanes. The lane besides road kerb is numbered 0. The number increases by 1 for each lane further away from the kerb. After the edge is highlighted, you can click the left mouse button and select the appropriate option from a popup menu. A dashed line is shown on any edge with a blocked lane. We show an example with two road edges. Both edges have a blocked lane. The left edge is highlighted. As Lane 0 is currently blocked, the popup menu shows the option to unblock the lane. Lane 1 is not blocked so the popup menu shows the option to block the lane.