



Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Lecture with Computer Exercises:
Modelling and Simulating Social Systems with MATLAB

Project Report

Intersection Problem
Traffic flow comparison of roundabouts with crossroads
controlled by trafficlights, including pedestrians

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Zurich
Dec 2012

Agreement for free-download

We hereby agree to make our source code for this project freely available for download from the web pages of the SOMS chair. Furthermore, we assure that all source code is written by ourselves and is not violating any copyright restrictions.

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1 Abstract

In our simulation, based on cellular automata, we have tried to compare roundabouts to crossroads, controlled by traffic lights, with respect to the traffic flow. We defined the flow as the product of car density and average speed of the cars. Our main input parameters are car density and pedestrian density. Some results here???

2 Individual contributions

3 Introduction and Motivations

Several groups in this course have simulated roundabouts and crossroads before. Our work is a development of and in addition to Traffic Dynamics, written by Tony Wood and Bastian Bcheler in May 2010. In difference to their simulation we added pedestrians and implemented crossroads with lights instead of priority to the right organisation. They showed impressively, that roundabouts are much more efficient than crossroads, nearly independent of the car density. They have concluded, that their model confirms, that the increase in popularity of roundabouts over the last years is justified. In our view one important parameter was missing: the pedestrian density. As we have lived so far in cities, we have had occasions enough to observe that in the mornings and evenings some large roundabouts are just blocked, when pedestrians are allowed to cross the streets, especially when in the middle of the roundabout is a station for trams or buses. Depending on the pedestrian density we have implemented three different signalisation modes in the crossroads. For high pedestrian densities there won't be any conflicts between pedestrians and cars. So we thought that at least at this stage, crossroads may be in advantage to roundabouts. Some results

4 Description of the Model and Implementation

4.1 Description of the main function

In our model one can compare roundabouts with crossroads, controlled by traffic lights. One can use an arbitrary combination of roundabouts and crosslights in a $N \times M$ map.

Main input of the simulation are car and pedestrian densities, which can be entered as arrays. The simulation can be done with different probabilities for the car to go straight ahead. Cars turning left or right will have the same probability. The simulation will generate a plot over these densities as x- and y- axis and the average flow and average speed as z-axis in different colors.

$$flow = density \cdot speed$$

4.1.1 Implementation

We have created a big matrix to display the simulation, containig all roads and intersections. Cars will be painted in blue and pedestrians in yellow. Many matrices

more are needed to store status informations that can change. So for most following matrices, there are two versions, representing current and next status. After every iteration status next will assigned to current.

4.2 crossroad

Depending on the pedestrian density, there are three different signalisation modes. For densities smaller than 0.3, cars that turn can always be blocked currently by a pedestrian. If the density is between 0.3 and 0.6, they can only block cars turning left. And if the density is even higher there should be no conflicts between cars and pedestrians. But if the car densities are very high, it can happen that the fixed yellow phase for changing the signalisation is too short to let all the cars leave the crossroad.

A further input parameter in the main-function is the probability of a car driving straight ahead. Cars that turn left and right have the same probability. So depending on these probabilities the relative time for light phases are different. To get the absolute time of a phase, one has to multiply it with a constant, indicating how often you change the signalisation.

It would be efficient if cars leaving one intersection would just arrive at the next one in a green-phase, so that the crossroad could take advantage of the randomisation process when entering a roundabout. A clever solution for this interesting problem is left to a next group, hopefully. We just added a phase offset between two crossroads, defined by the average time a car needs to drive from one intersection to the next and the fixed street lengths.

In contrast to the simulation of Wood and Bcheler and to the roundabout, cars entering the crossroad can have speed bigger than one cell per iteration. So cars can drive straight ahead with maximal speed of 5 cells according to the Nagel-Schreckenberg model. Cars turning left or right are limited to maximal 2 cells per iteration.

4.2.1 Implementation

A crossroad consists of three 6×6 -Matrices, so that for every cell information about is there a car, its speed and direction can be stored. Furthermore two 4×8 -Matrix for 4 lanes of length 8 cells at every street heading towards the crossroad for cars turning left are needed to decide if there's a car and store its speed. For cars driving ahead or turning right one 4×8 -Matrix indicates the direction.

4.3 Roundabout

Our implementation of the roundabout consists of a circle with 12 cells and 4 roads, which lead towards it. Every street has pedestrian crossings in front of each roundabout. Like in the real world, cars inside the roundabout have priority over cars wanting to enter them and pedestrians have priority over cars at the pedestrian crossings, with the addition, that pedestrians will only walk on the road if there is no car staying or driving on the cell they want to walk on. Inside the crossroad the speed a car can have is limited to 1 cell per iteration step.

A car which wants to leave the roundabout at the next exit will indicate, in our plot this is shown by giving these cars a darker colour. The exit a car will take is calculated from the probability ahead like in the crossroad, but with a fixed probability of 5 % for a car which will take the 4th exit (i.e. the car will turn around).

4.3.1 Implementation

This is implemented with many arrays, three arrays for the circle, one which shows whether there is a car or not, and if the car wants to leave at the next exit. The second is used to store the velocity of the car and the third is used to store, how many exits the car will pass without leaving.

The entries and exits of the roundabout are randomly blocked by pedestrians. For this reason two 'buckets' are created, representing pedestrian islands between inwards and outgoing streets. If a pedestrian crosses an outgoing street, the bucket makes sure, that in the next iteration inwards street will be blocked.

5 Execution and User Instructions

5.1 User Instructions

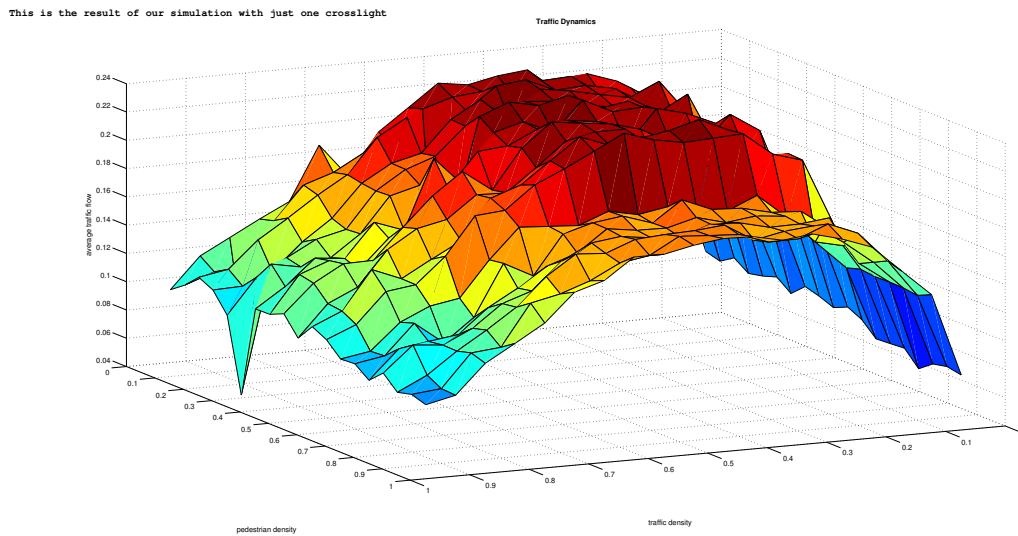
The Simulation consists of total 14 functions. Our main-function to be executed is called traffic. The user will be asked, what city configuration he would like to simulate. The input has to be a $N \times M$ -Matrix with entries 0=roundabout or 1=crossroad. Then car density, probability for car driving ahead and pedestrian density are numbers between 0 and 1. A density of 0 means no cars, whereas 1 means on every single cell except the ones in the intersections stays a car. Densities can be entered as arrays, so the simulation will run for every single entry. Afterwards the user can decide, whether he wants to display the simulation, if slow motion is required and if

he wants to store the data average speed and average flow.

5.2 Execution

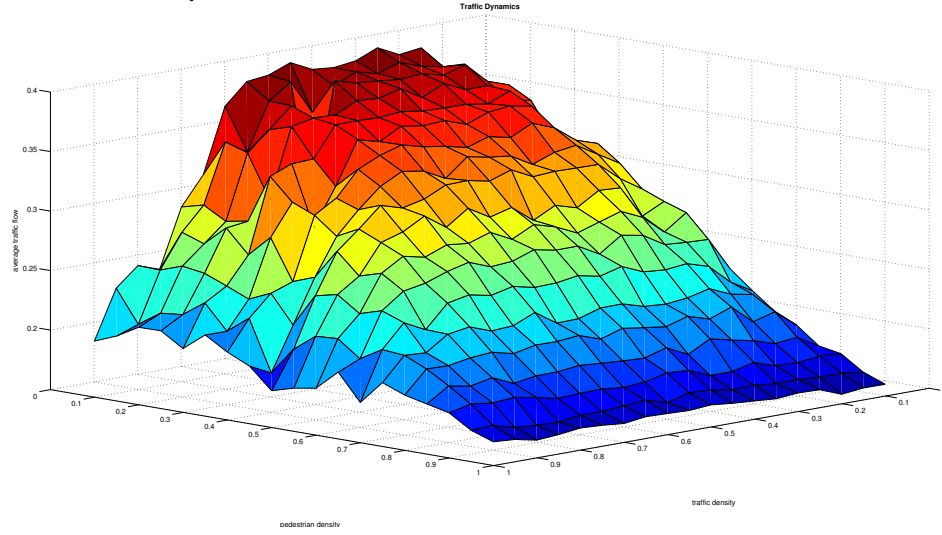
The user should start `traffic.m` and answer the questions he will be asked. `traffic.m` will then load `trafficloop.m` which will then call `trafficsim.m`. In `trafficsim.m` is our main loop for every simulation. Here the output graphics, videos etc. will be created.

6 Simulation Results and Discussion



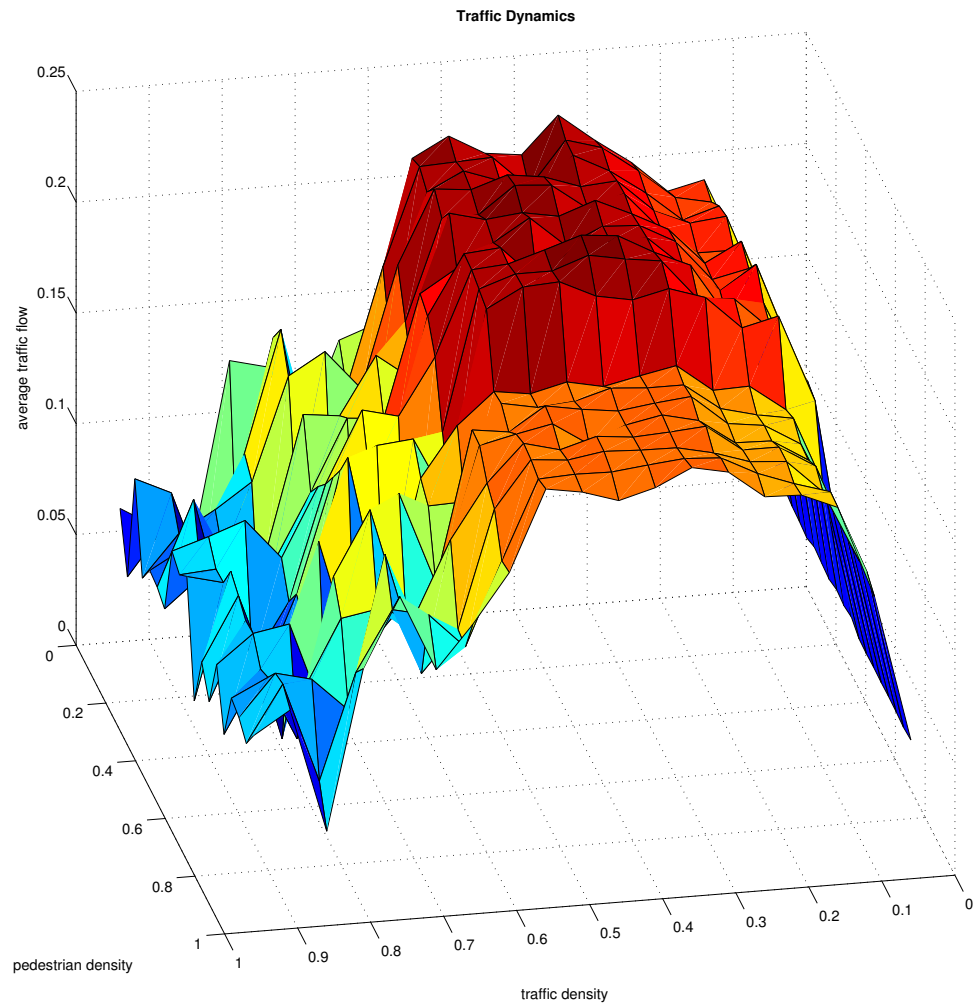
In this plot of one crosslight, one can clearly see the linear increase of traffic flow with increasing car density till 0.25 after that it is more or less constant till it drops linearly at car densities higher than 0.6. One can also see that it does depend only weakly on the pedestrian density, but for high pedestrian densities above 0.8 we see a small drop. (caused by a different traffic light mode)

This is the result of our simulation with just one roundabout



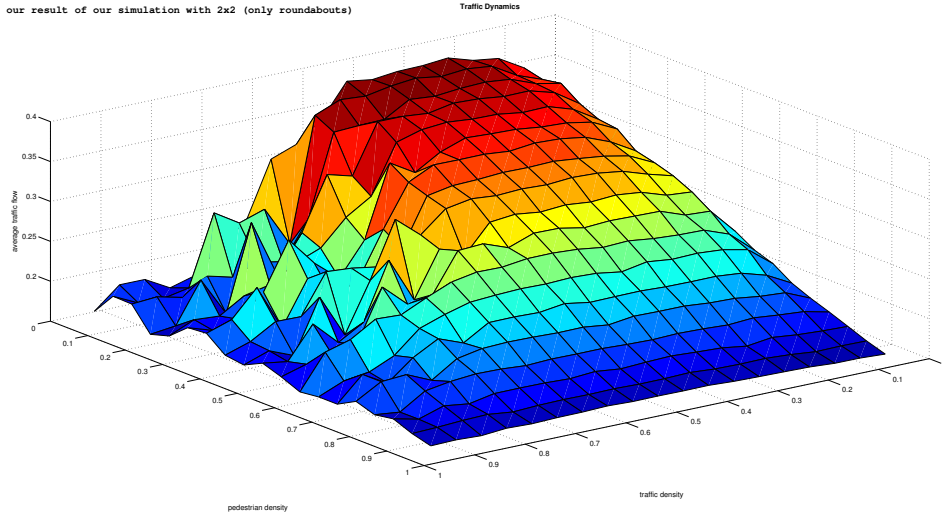
In this plot of one roundabout the linear decrease in flow with increasing pedestrian density is clearly visible. And for a const. pedestrian density one sees also the expected result, which is a linear increase, then for some time a const flow and ending with a linear decrease for increasing car densities. Compared to the flow of one traffilight one can see that a roundabout is much more efficient (almost twice the flow) for low pedestrian densities and less efficient for low densities.

This is the result of our simulation with 2x2 (only trafficlight)



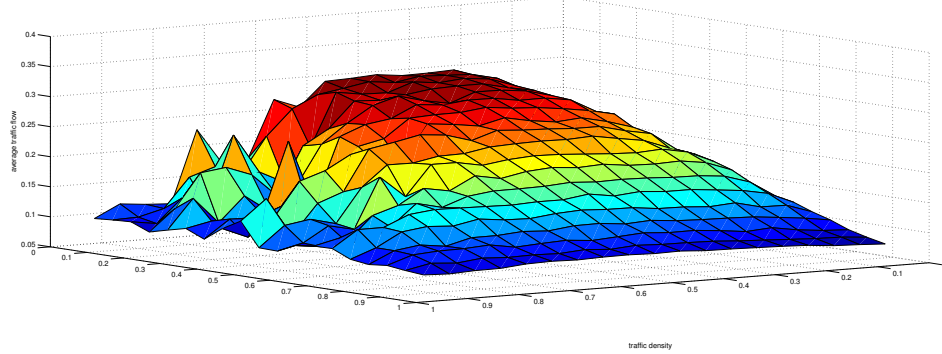
This result does not differ much from the result with just one trafficlight, but one can see that the linear in-/decrease has a higher slope.

This is our result of our simulation with 2x2 (only roundabouts)



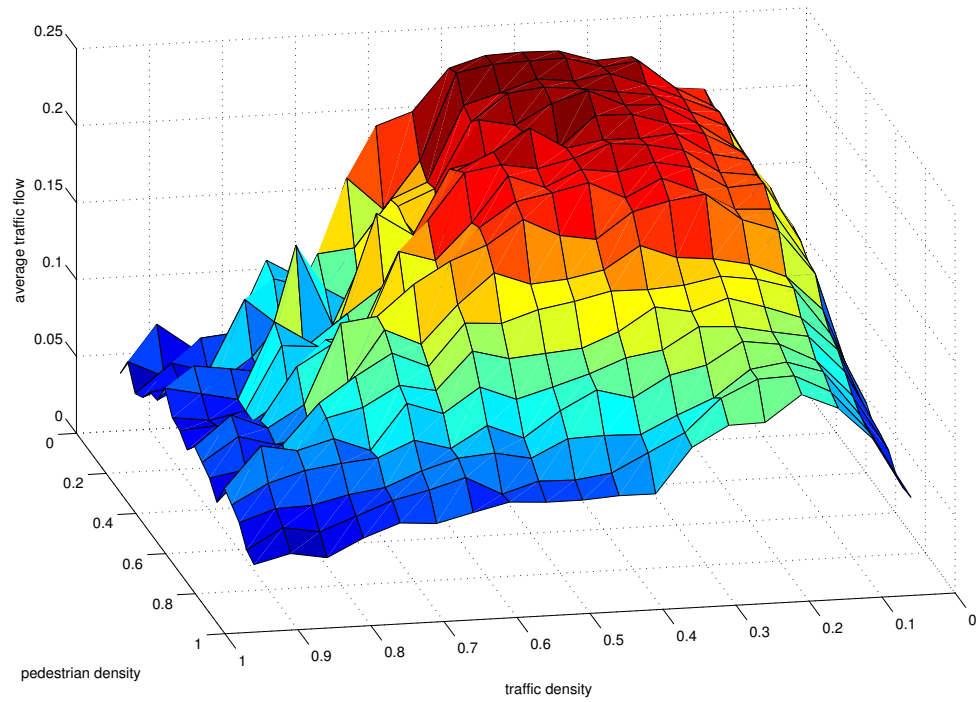
This result does not differ much from the single roundabout either, but here the slope of the linear decrease with increasing pedestrian densities is smaller.

This is our result of our simulation with 2x2 (with 2 crosslights and 2 roundabouts)



In the combination case of both methods, the characteristic looks dominated by the roundabout (i.e. it does not look much different to the graph above) but here the flow rates are lower. With higher car densities random processes are getting more important and thus the graph does not look so smooth anymore.

This is the result of our simulation with 3x3 (1 roundabout in the middle, the rest crossli
Traffic Dynamics



Here it is visible, that just one roundabout in the middle is able to block for high pedestrian densities, were as for lower ones this is clearly dominated by the eight trafficlights.

7 Summary and Outlook

List of Figures

A Listings

A.1 Matlab Codes

Listing 1: traffic.m

```
1 function traffic
2 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
3 %TRAFFIC Simulation of traffic in an city map containing roundabouts and
4 %crossroads.
5 %
6 %This program requires the following subprogams:
7 %TRAFFICLOOP,TRAFFICSIM,ROUNDABOUT,CROSSROAD,CONNECTION,PDESTINATION
8 %
9 %
10 %User will be ask to determine city map,car density , pedestrian density , pahead,
    whether
11 %simulation is to be displayed or not, if the user wants to create a video
12 %of the simulation , if the user wants to show the simulaztion in slowmotion
13 %and if he wants to store the results to plot them later
14 %
15 %The city map is entered by supplying a matrix with elements '1' for
16 %crossroads and '0' for roundabouts.
17 %
18 %The density can be a scalar or a vector. If the density is a scalar
19 %TRAFFIC will run the simulation for all densities given. The elements must
20 %be in the range of [0,1].
21 %
22 %If Users chooses to display simulation (by entering 'y') a figure will
23 %open showing the animation
24 %
25 %After all simulations have finished TRAFFIC plots the average traffic flow
26 %versus the traffic density. If city map is a mix of crossroad and
27 %roundabouts the traffic distribution (cars around roundabouts or around
28 %crossroads) versus traffic density is also plotted.
29 %
30 %A project by Marcel Arikan, Nuhro Ego and Ralf Kohrt in the GeSS course "Modelling
31 %and Simulation of Social Systems with MATLAB" at ETH Zurich.
32 %Fall 2012
33 %Matlab code is based on code from Bastian Buecheler and Tony Wood in the GeSS
    course "Modelling
34 %and Simulation of Social Systems with MATLAB" at ETH Zurich.
35 %Spring 2010
36 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
37
38 close all;
39
40 %prompt city road configutation
41 c = input(['\nenter city map\n\ngive matrix elements: ', ...
42     'Priority to the right (=1) and Roundabout (=0) \n\n', ...
43     'i.e. [1 0 0;1 1 0;0 1 1]\n\n']);
44
45 %check c
46 [c_m,c_n] = size(c);
47 for a = 1:c_m
48     for b = 1:c_n
49         if ( c(c_m,c_n) ~= 1 && c(c_m,c_n) ~= 0 )
```

```

50         disp('Elements must be 0 or 1');
51         return
52     end
53 end
54 end
55
56 %prompt traffic density
57 d = input('\nenter car traffic density: ');
58 %check d
59 if ( max(d) > 1 || min(d) < 0)
60     disp('density must be in range [0,1]');
61     return
62 end
63
64 %prompt probability for car driving ahead
65 pahead = input('\nenter probability for car driving ahead: ');
66 %check pahead
67 if (max(pahead) > 1 || min(pahead) < 0)
68     disp('probability must be in range [0,1]');
69     return
70 end
71
72 %prompt pedestrian density
73 pd = input('\nenter pedestrian traffic density: ');
74 %check pd
75 if ( max(pd) > 1 || min(pd) < 0)
76     disp('density must be in range [0,1]');
77     return
78 end
79
80 %ask if simulation should be displayed
81 show = input('\ndisplay simulation graphically? yes (=y) or no (=n) ', 's');
82
83 %ask if simulation should be in slow_motion
84 slow_motion = input('\ndisplay slow-motion? yes (=y) or no (=n) ', 's');
85 if (slow_motion == 'n')
86     slow_motion = 0;
87 end
88
89 video = input('\ncreate video? yes (=y) or no (=n) ', 's');
90 if (video == 'n')
91     video = 0;
92 end
93
94
95 store_results = input('\nstore results? yes (=y) or no (=n) ', 's');
96 if (store_results == 'n')
97     store_results = 0;
98 end
99 if(store_results)
100     folder = input('\nin which folder do you want to store your results?');
101     filename = sprintf('../results/%g/config', folder);
102     save(filename, 'c', 'pahead');
103     trafficloop(c, d, pahead, pd, show, slow_motion, video, store_results, folder);
104 else
105     trafficloop(c, d, pahead, pd, show, slow_motion, video, store_results, 'n');
106 end
107

```

108
109 end

Listing 2: trafficloop.m

```
1 function trafficloop(c, d, pahead, pd, show, slow_motion, video, store_results,
   folder)
2 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
3 %TRAFFIC Simulation of traffic in an city map containing roundabouts and
4 %crossroads.
5 %
6 %This program requires the following subprogams:
7 %TRAFFICSIM, ROUNDABOUT, CROSSROAD, CONNECTION, PDESTINATION
8 %
9 %
10 %This is the main loop of our simulation
11 %
12 %A project by Marcel Arian, Nuhro Ego and Ralf Kohrt in the GeSS course "Modelling
13 %and Simulation of Social Systems with MATLAB" at ETH Zurich.
14 %Fall 2012
15 %Matlab code is based on code from Bastian Buecheler and Tony Wood in the GeSS
   course "Modelling
16 %and Simulation of Social Systems with MATLAB" at ETH Zurich.
17 %Spring 2010
18 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
19
20
21 %%%
22 % define global variables
23 BUILDING = 0; %the colour for buildings
24 EMPTY_STREET = 1;
25 CAR = 0.4;
26 CAR_NEXT_EXIT = 0.6; %the colour of a car which will take the next exit
27 PEDESTRIAN = 0.8;
28
29 STREET_INTERSECTION = 7; %STREET_INTERSECTION specifies the number of elements of
   the road which will be taken care of by the crossroad/roundabout
30
31
32 if(store_results)
33     filename = sprintf(' ../results/%g/config', folder);
34     save(filename, 'c', 'pahead');
35     result = ones(1,4);
36 end
37
38 %%% runtime measurement - start
39 tic;
40
41 [c_m, c_n] = size(c);
42 %check if city map is a mix of crossroads and roundabouts or if it is made up
43 %purely of one or the other
44 mix = not( sum(sum(c)) == c_m * c_n || sum(sum(c)) == 0 );
45
46 %average flow and distributions for every density supplied
47 avFlow = zeros(max(size(pd)), max(size(d)));
48 avRo = zeros(max(size(pd)), max(size(d)));
49 avCr = zeros(max(size(pd)), max(size(d)));
50
```

```

51 if ( show == 'y' || show == 'n' ) %if show == 'y' -> simulation with graphic
    output
52
53     for di=1:max(size(d))
54         for pdi=1:max(size(pd))
55             if(store_results)
56                 [config_m, config_n] = size(c);
57                 filename = sprintf(' ../ results/%g/result_(%g x %g)_%g_%g.mat',
58                     folder, config_m, config_n, ...
59                     d(di), pd(pdi));
60                 disp(filename);
61                 [a1,a2,a3,a4] = trafficsim(d(di),pd(pdi),c,show == 'y', ...
62                     BUILDING,EMPTY_STREET,CAR,CAR_NEXT_EXIT,PEDESTRIAN,
63                     STREET_INTERSECTION, ...
64                     pahead, slow_motion, video);
65                 result(1) = a1;
66                 result(2) = a2;
67                 result(3) = a3;
68                 result(4) = a4;
69                 disp(result);
70                 save(filename, 'result');
71             else
72                 [avFlow(pdi, di), avRo(pdi, di), avCr(pdi, di)] = trafficsim(d(di),pd(pdi),
73                     c,show == 'y', ...
74                     BUILDING,EMPTY_STREET,CAR,CAR_NEXT_EXIT,PEDESTRIAN,
75                     STREET_INTERSECTION, ...
76                     pahead, slow_motion, video);
77             end
78         end
79     end
80
81     if(store_results == 0)
82         figure(2);
83         %is city map is a mix of roundabout and crossroads, plot distribution
84         if ( mix )
85             %plot relativ number of cars at roundabouts and number of cars at
86             %crossroads versus traffic density
87             subplot(2,1,2);
88             plot(d,avRo*100,'rx',d,avCr*100,'gx');
89             set(gca,'FontSize',16);
90             title('Traffic Distribution');
91             xlabel('traffic density');
92             ylabel('relative numeber of cars [%]');
93             legend('around roundabouts','around crossroads');
94             ylim([0 100]);
95             subplot(2,1,1);
96         end
97
98         %plot traffic flow versus traffic density
99         plot(d,avFlow,'x');
100         set(gca,'FontSize',16);
101         title('Traffic Dynamics');
102         xlabel('traffic density');
103         ylabel('average traffic flow');
104         ylim([0 0.5]);
105     end
106 else
107     disp('Input must be y or n!');
108 end

```



```

104 end
105
106 %%% runtime measurement — end
107 toc;
108
109 end

```

Listing 3: trafficsim.m

```

1 function [averageFlow,avCaRo,avCaCr,averageSpeed] = trafficsim(car_density ,
    pedestrian_density,config,display, ...
2     BUILDING,EMPTY_STREET,CAR,CAR_NEXT_EXIT,PEDESTRIAN,STREET_INTERSECTION, pahead ,
    slow_motion , video)
3 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
4 %TRAFFICSIM Simulation of traffic in an city map containing roundabouts and
5 %crosslights.
6 %
7 %Output:
8 %AVERAGEFLOW, Average traffic flow for given city map and density
9 %AVCARO, Average amount of cars around roundabouts
10 %AVCACR, Average amount of cars around crossroads
11 %averageSpeed, Average speed
12 %
13 %INPUT:
14 %CAR_DENSITY, CAR traffic density
15 %PEDESTRIAN_DENSITY, pedestrian traffic density
16 %CONFIG, City map
17 %DISPLAY, Turn graphics on 'true' or off 'false'
18 %+defined 'global' variables BUILDING,EMPTY_STREET,CAR,CAR_NEXT_EXIT,PEDESTRIAN,
    STREET_INTERSECTION
19 %PAHEAD, pobability for a car to go ahead
20 %SLOW_MOTION, show graphics in slow motion?
21 %VIDEO, generate a video?
22 %
23 %This program requires the following subprogams:
24 %ROUNDABOUT,CROSSLIGHT,CONNECTION,PDESTINATION,MEASURE_GAP,SCHRECKENBERG,PLOT_MAP
25 %
26 %A project by Marcel Arikan, Nuhro Ego and Ralf Kohrt in the GeSS course "Modelling
27 %and Simulation of Social Systems with MATLAB" at ETH Zurich.
28 %Fall 2012
29 %Matlab code is based on code from Bastian Buecheler and Tony Wood in the GeSS
    course "Modelling
30 %and Simulation of Social Systems with MATLAB" at ETH Zurich.
31 %Spring 2010
32 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
33
34 %dawde probability
35 dawdleProb = 0.2;
36 %street length (>5)
37 street_length = 30;
38 %number of iterations
39 nIt=1001;
40
41 %dimensions of config, how many intersections in x and y direction are
42 %there?
43 [config_m,config_n] = size(config);
44
45 %initialize matrices for streets heading toward intersections

```

```

46 | street_inwards = ones(4*config_m,street_length*config_n)*EMPTY_STREET;
47 | inwards_speed = zeros(4*config_m,street_length*config_n);
48 | %number of elements in street_inwards
49 | inwards_size = sum(sum(street_inwards));
50 |
51 | %initialize matrices for street leading away from intersections
52 | street_outwards = ones(4*config_m,street_length*config_n)*EMPTY_STREET;
53 | outwards_speed = zeros(4*config_m,street_length*config_n);
54 |
55 | %initialize matrices for roundabouts
56 | street_roundabout = ones(config_m,12*config_n)*EMPTY_STREET;
57 | roundabout_speed = zeros(config_m,12*config_n);
58 | roundabout_exit = zeros(config_m,12*config_n);
59 |
60 | %initialize matrices for crossings
61 | street_crossroad = ones(6*config_m,6*config_n)*EMPTY_STREET;
62 |
63 | crossroad_speed = zeros(6 *config_m,6*config_n);
64 | crossroad_exit = zeros(6*config_m,6*config_n);
65 | trace_left=ones(4*config_m,(STREET_INTERSECTION+1)*config_n)*EMPTY_STREET;
66 | trace_left_speed=zeros(4*config_m,(STREET_INTERSECTION+1)*config_n);
67 | trace_right_direction=zeros(4*config_m,(STREET_INTERSECTION+1)*config_n);
68 |
69 | %this are the computed gaps from the crossections/roundabouts
70 | inwards_gaps = zeros(config_m,config_n*4);
71 |
72 | pedestrian_bucket = zeros(2*config_m,4*config_n);
73 |
74 | %initialize flow calculation variables
75 | avSpeedIt = zeros(nIt+1,1);
76 | %counter for cars around crossroads
77 | numCaCrIt = zeros(nIt+1,1);
78 | %counter for cars around crossroads
79 | numCaRoIt = zeros(nIt+1,1);
80 |
81 | %distribute cars randomly on streets for starting point
82 | overall_length = sum(sum(street_inwards)) + sum(sum(street_outwards));
83 | numCars = ceil(car_density * overall_length);
84 | q = 1;
85 |
86 | while ( q <= numCars )
87 |     w = randi(overall_length,1);
88 |     if ( w <= inwards_size )
89 |         if ( street_inwards(w) == EMPTY_STREET)
90 |             street_inwards(w) = CAR;
91 |             inwards_speed(w) = randi(5,1);
92 |             q = q + 1;
93 |         end
94 |     end
95 |     if ( w > inwards_size )
96 |         if ( street_outwards(w-inwards_size) == EMPTY_STREET)
97 |             street_outwards(w-inwards_size) = CAR;
98 |             outwards_speed(w-inwards_size) = randi(5,1);
99 |             q = q +1 ;
100 |         end
101 |     end
102 | end
103 |

```

```

104
105 street_roundabout_next = ones(config_m,12*config_n)*EMPTY_STREET;
106 roundabout_speed_next = zeros(config_m,12*config_n);
107 street_crossroad_next = ones(6*config_m,6*config_n)*EMPTY_STREET;
108 crossroad_speed_next = ones(6*config_m,6*config_n);
109 crossroad_exit_next = zeros(6*config_m,6*config_n);
110
111 light=zeros(config_m, 12*config_n);      %to display light signalisation
112
113 %variables for traffic light control
114 switchtime = 3;      %time to change signalement (yellow phase)
115 lighthlength = 30;   %time for staying in same signalement phase
116 aheadphase = ceil((lighthlength*pahead)/switchtime);      %time to keep green phase
    ahead
117 turnphase = ceil((lighthlength*(1-pahead)/2)/switchtime);      %time to keep green
    phase when turning
118 totalphase = 6 + 2*aheadphase + 4*turnphase;      %to reset the phase
119 count =0;      %counter
120 phase=0;
121 traveltime = 15+105*car_density;      %time a car needs from one intersection to the
    next
122
123 %figure and video
124 if (display)
125     %figure for map plotting
126     fig1 = figure(1);
127     load('colormaps/colormap4', 'mycmap');
128     set(fig1, 'Colormap', mycmap);
129     titlestring = sprintf('Density = %g', car_density);
130
131     %create video
132     if (video)
133         filename = sprintf('videos/video_(%g x %g)_%g_%g.avi', config_m, config_n,
            ...
            car_density, pedestrian_density);
134         vidObj = VideoWriter(filename);
135         open(vidObj);
136     end
137 end
138
139 %iterate over time
140 for time = 1:nIt+1
141
142     %clear values for next step
143     street_inwards_next = ones(4*config_m,street_length*config_n)*EMPTY_STREET;
144     inwards_speed_next = zeros(4*config_m,street_length*config_n);
145     street_outwards_next = ones(4*config_m,street_length*config_n)*EMPTY_STREET;
146     outwards_speed_next = zeros(4*config_m,street_length*config_n);
147     trace_left_next=zeros(4*config_m,(STREET_INTERSECTION+1)*config_n);
148     trace_left_speed_next=zeros(4*config_m,(STREET_INTERSECTION+1)*config_n);
149     trace_right_direction_next=zeros(4*config_m,(STREET_INTERSECTION+1)*config_n);
150
151
152     %calculate taffic light phase
153     if (count == switchtime)
154         if (phase == totalphase+1)
155             phase = 0;
156         end
157

```

```

158     phase = phase+1;
159     count = 0;
160 else
161     count = count +1;
162 end
163
164 %iterate over all intersection
165 for a = 1:config_m
166     for b = 1:config_n
167
168         %define Index starting points for each intersection
169         tI_m = (a - 1) * 4;
170         tI_n = (b - 1) * street_length;
171
172         %positions outside intersections
173         %for every intersection iterate along streets
174         for c = tI_m + 1:tI_m +4
175             for d = tI_n + 1:tI_n+street_length
176
177                 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
178                 %streets to intersections
179
180                 %deal with the STREET_INTERSECTION positions directly in front
181                 %of intersection
182                 %separately later
183                 if ( d-tI_n < street_length-STREET_INTERSECTION)
184                     %if there is a car in this position , apply
185                     %NS-Model
186                     if ( street_inwards(c,d) == CAR )
187                         %Nagel-Schreckenberg-Model
188                         gap = measure_gap(street_inwards , street_outwards ,
189                                         street_length , a , b , c , d , 1 , ...
190                                         inwards_gaps(a,(b - 1) *4+c-tI_m), config_m ,
191                                         config_n , EMPTY_STREET,STREET_INTERSECTION);
192                         v = schreckenberg(inwards_speed(c,d) , gap , dawdleProb);
193
194                         %NS 4. step: drive , move cars tspeed(c,d) cells
195                         %forward
196                         %new position
197                         street_inwards_next(c,d+v) = CAR;
198                         inwards_speed_next(c,d+v) = v;
199                     end
200                 end
201
202                 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
203                 %street from intersections
204
205                 %deal with the STREET_INTERSECTION positions directly after the
206                 %intersection
207                 %separately later
208                 if ( d-tI_n > STREET_INTERSECTION)
209                     if ( street_outwards(c,d) == CAR )
210                         %Nagel-Schreckenberg-Model
211                         gap = measure_gap(street_inwards , street_outwards ,
212                                         street_length , a , b , c , d , 0 , 0 , ...
213                                         config_m , config_n , EMPTY_STREET,STREET_INTERSECTION
214                                         );
215                         v = schreckenberg(outwards_speed(c,d) , gap , dawdleProb);

```

```

210
211         %NS 4. step: drive, move cars fspeed(c,d) cells
212         %forward
213         %if new position is off this street, connect
214         %streets
215         if ( d + v > b * street_length )
216             %position in new street
217             hhh = d + v - b * street_length;
218             %connect next street
219             [ec,ed] = connection(a,b,c,hhh, ...
220                 config_m,config_n,street_length);
221             street_inwards_next(ec,ed) = CAR;
222             inwards_speed_next(ec,ed) = v;
223         else
224             street_outwards_next(c,d+v) = CAR;
225             outwards_speed_next(c,d+v) = v;
226         end
227     end
228 end
229 end
230 end
231
232 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
233 %roundabouts
234
235 %check if intersection is a roundabout
236 if ( config(a,b) == 0 )
237     %define index strating point for this roundabout
238     rI_n = (b - 1) * 12;
239
240     %do roundabout calculations for this roundabout and time
241     %step
242     %call ROUNDABOUT
243     [street_inwards_next(tI_m+1:tI_m+4,tI_n+street_length-
244         STREET_INTERSECTION:tI_n+street_length), ...
245         inwards_speed_next(tI_m+1:tI_m+4,tI_n+street_length-
246             STREET_INTERSECTION:tI_n+street_length), ...
247         street_outwards_next(tI_m+1:tI_m+4,tI_n+1:tI_n+
248             STREET_INTERSECTION+6), ...
249         outwards_speed_next(tI_m+1:tI_m+4,tI_n+1:tI_n+
250             STREET_INTERSECTION+6), ...
251         street_roundabout_next(a,rI_n+1:rI_n+12), ...
252         roundabout_speed_next(a,rI_n+1:rI_n+12), ...
253         roundabout_exit(a,rI_n+1:rI_n+12), ...
254         pedestrian_bucket((a-1)*2+1:(a-1)*2+2,(b - 1) *4+1:(b - 1) *4+4)
255         , ...
256         inwards_gaps(a,(b - 1) *4+1:(b - 1) *4+4) ] = ...
257         roundabout(street_inwards(tI_m+1:tI_m+4,tI_n+street_length-
258             STREET_INTERSECTION:tI_n+street_length), ...
259         inwards_speed(tI_m+1:tI_m+4,tI_n+street_length-
260             STREET_INTERSECTION:tI_n+street_length), ...
261         street_outwards(tI_m+1:tI_m+4,tI_n+1:tI_n+STREET_INTERSECTION+6)
262         , ...
263         outwards_speed(tI_m+1:tI_m+4,tI_n+1:tI_n+STREET_INTERSECTION+6),
264         ...
265         street_roundabout(a,rI_n+1:rI_n+12), ...
266         roundabout_exit(a,rI_n+1:rI_n+12), ...
267         pedestrian_bucket((a-1)*2+1:(a-1)*2+2,(b - 1) *4+1:(b - 1) *4+4)

```

```

259         , ...
260         pedestrian_density , ...
261         street_inwards_next (tI_m+1:tI_m+4,tI_n+street_length-
                STREET_INTERSECTION:tI_n+street_length), ...
262         inwards_speed_next (tI_m+1:tI_m+4,tI_n+street_length-
                STREET_INTERSECTION:tI_n+street_length), ...
263         street_outwards_next (tI_m+1:tI_m+4,tI_n+1:tI_n+
                STREET_INTERSECTION+6), ...
264         outwards_speed_next (tI_m+1:tI_m+4,tI_n+1:tI_n+
                STREET_INTERSECTION+6),EMPTY_STREET,CAR,CAR_NEXT_EXIT,
                PEDESTRIAN,STREET_INTERSECTION,pahead);

265
266         %add cars around this crossroad in this time step to
267         %counter for cars around crossroads
268         for v = tI_m+1:tI_m+4
269             for w = tI_n+1:tI_n+street_length
270                 if ( street_inwards(v,w) ~= 1 )
271                     numCaRoIt(time) = numCaRoIt(time) + 1;
272                 end
273                 if ( street_outwards(v,w) ~= 1 )
274                     numCaRoIt(time) = numCaRoIt(time) + 1;
275                 end
276             end
277         end
278         for y = rI_n+1:rI_n+12
279             if ( street_roundabout(a,y) ~= 1 )
280                 numCaRoIt(time) = numCaRoIt(time) + 1;
281             end
282         end
283     end
284 end
285
286 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
287 %crossroads
288
289 %check if intersection is a crossing with priority to the right
290 if ( config(a,b) == 1 )
291     %define index starting points for this crossraod
292     pI_m = (a - 1) * 6;
293     pI_n = (b - 1) * 6;
294
295     %define trace index for this crossraod
296     traceI_m = (a - 1) * 4;
297     traceI_n = (b - 1) * 8;
298     %define light index for this crossroad
299     lightI_m = (a - 1) ;
300     lightI_n = (b - 1) * 12;
301     %calculate local off set of phase for different crossroads
302     localphase = phase+(a+b-2)*traveltime;
303     while (localphase > totalphase) %reset localphase if
        necessary
304         localphase = localphase - totalphase;
305     end
306     %do crossroad calculations for this crossroad and time step
307     %call CROSSROAD
308     [street_inwards_next(tI_m+1:tI_m+4,tI_n+street_length-
        STREET_INTERSECTION:tI_n+street_length), ...

```

```

309     inwards_speed_next(tI_m+1:tI_m+4,tI_n+street_length-
        STREET_INTERSECTION:tI_n+street_length), ...
310     street_outwards_next(tI_m+1:tI_m+4,tI_n+1:tI_n+
        STREET_INTERSECTION+6), ...
311     outwards_speed_next(tI_m+1:tI_m+4,tI_n+1:tI_n+
        STREET_INTERSECTION+6), ...
312     street_crossroad_next(pI_m+1:pI_m+6,pI_n+1:pI_n+6), ...
313     crossroad_speed_next(pI_m+1:pI_m+6,pI_n+1:pI_n+6), ...
314     crossroad_exit_next(pI_m+1:pI_m+6,pI_n+1:pI_n+6), ...
315     pedestrian_bucket((a-1)*2+1:(a-1)*2+2,(b-1)*4+1:(b-1)*4+4)
        , ...
316     inwards_gaps(a,(b-1)*4+1:(b-1)*4+4), ...
317     trace_left_next(traceI_m+1:traceI_m+4,traceI_n+1:traceI_n+8),
        ...
318     trace_left_speed_next(traceI_m+1:traceI_m+4,traceI_n+1:traceI_n
        +8), ...
319     trace_right_direction_next(traceI_m+1:traceI_m+4,traceI_n+1:
        traceI_n+8), ...
320     light(lightI_m+1,lightI_n+1:lightI_n+12)] ...
321     = crosslight(street_inwards(tI_m+1:tI_m+4,tI_n+street_length-
        STREET_INTERSECTION:tI_n+street_length), ...
322     inwards_speed(tI_m+1:tI_m+4,tI_n+street_length-
        STREET_INTERSECTION:tI_n+street_length), ...
323     street_outwards(tI_m+1:tI_m+4,tI_n+1:tI_n+STREET_INTERSECTION+6)
        , ...
324     outwards_speed(tI_m+1:tI_m+4,tI_n+1:tI_n+STREET_INTERSECTION+6),
        ...
325     street_crossroad(pI_m+1:pI_m+6,pI_n+1:pI_n+6), ...
326     crossroad_speed(pI_m+1:pI_m+6,pI_n+1:pI_n+6), ...
327     crossroad_exit(pI_m+1:pI_m+6,pI_n+1:pI_n+6), ...
328     pedestrian_bucket((a-1)*2+1:(a-1)*2+2,(b-1)*4+1:(b-1)*4+4)
        , ...
329     inwards_gaps(a,(b-1)*4+1:(b-1)*4+4), dawdleProb, ...
330     pedestrian_density, ...
331     street_inwards_next(tI_m+1:tI_m+4,tI_n+street_length-
        STREET_INTERSECTION:tI_n+street_length), ...
332     inwards_speed_next(tI_m+1:tI_m+4,tI_n+street_length-
        STREET_INTERSECTION:tI_n+street_length), ...
333     street_outwards_next(tI_m+1:tI_m+4,tI_n+1:tI_n+
        STREET_INTERSECTION+6), ...
334     outwards_speed_next(tI_m+1:tI_m+4,tI_n+1:tI_n+
        STREET_INTERSECTION+6),EMPTY_STREET,CAR,CAR_NEXT_EXIT,
        PEDESTRIAN,STREET_INTERSECTION, ...
335     pahead, trace_left(traceI_m+1:traceI_m+4,traceI_n+1:traceI_n+8),
        trace_left_speed(traceI_m+1:traceI_m+4,traceI_n+1:traceI_n
        +8), trace_right_direction(traceI_m+1:traceI_m+4,traceI_n+1:
        traceI_n+8), ...
336     localphase, aheadphase, turnphase);
337
338
339     %add cars around this crossroad in this time step to
340     %counter for cars around crossroad
341     for v = tI_m+1:tI_m+4
342         for w = tI_n+1:tI_n+street_length
343             if ( street_inwards(v,w) ~= 1 )
344                 numCaCrIt(time) = numCaCrIt(time) + 1;
345             end
346             if ( street_outwards(v,w) ~= 1 )

```

```

347         numCaCrIt(time) = numCaCrIt(time) + 1;
348     end
349 end
350 end
351     for x = pI_m+1:pI_m+6
352         for y = pI_n+1:pI_n+6
353             if ( street_crossroad(x,y) ~= 0 )
354                 numCaCrIt(time) = numCaCrIt(time) + 1;
355             end
356         end
357     end
358 end
359 end
360
361 end
362 end
363
364 %calculate average velocity per time step
365 avSpeedIt(time) = ( sum(sum(inwards_speed)) + sum(sum(outwards_speed)) + ...
366     sum(sum(roundabout_speed)) + sum(sum(crossroad_speed)) ) / numCars;
367
368 %plot the map in this timestep into the figure
369 if (display)
370     map = plot_map(street_length, config, car_density, display, ...
371         street_inwards, street_outwards, street_roundabout, street_crossroad,
372         ...
373         BUILDING,EMPTY_STREET, light, trace_left, STREET_INTERSECTION);
374     %illustrate traffic situation (now, not of next time step)
375     imagesc(map);
376     title(titlestring, 'FontWeight','bold');
377     drawnow;
378     if (video)
379         % get the current frame
380         currFrame = getframe(fig1);
381         % add the current frame
382         writeVideo(vidObj,currFrame);
383     end
384 end
385
386 if (slow_motion)
387     pause(1);
388 end
389
390 %move on time step on
391 street_inwards = street_inwards_next;
392 inwards_speed = inwards_speed_next;
393 street_outwards = street_outwards_next;
394 outwards_speed = outwards_speed_next;
395 street_roundabout = street_roundabout_next;
396 roundabout_speed = roundabout_speed_next;
397 street_crossroad = street_crossroad_next;
398 crossroad_speed = crossroad_speed_next;
399 crossroad_exit = crossroad_exit_next;
400 trace_left = trace_left_next;
401 trace_left_speed = trace_left_speed_next;
402 trace_right_direction = trace_right_direction_next;
403 end

```



```

404
405 if (video)
406     close(vidObj);
407 end
408
409 %overall average velocity
410 averageSpeed = sum(avSpeedIt) / max(size(avSpeedIt));
411 %overall average flow
412 averageFlow = car_density * averageSpeed;
413
414 %average relative amount of cars around roundabouts
415 avCaRo = sum(numCaRoIt) / ( max(size(numCaRoIt)) * numCars );
416 %average relative amount of cars around crossroads
417 avCaCr = sum(numCaCrIt) / ( max(size(numCaCrIt)) * numCars );
418
419 end

```

Listing 4: measure-gap.m

```

1 function [ gap ] = measure_gap(street_inwards, street_outwards, street_length, a, b,
   c, d, inwards, inwards_gap, config_m, config_n, EMPTY_STREET, STREET_INTERSECTION
   )
2 %MEASURE_GAP this measures the gap to the next car
3 % how big is gap (to car ahead or intersection)?
4
5
6 e = 0;
7 iterate = 1;
8 while (iterate) %iterate while iterate is 1
9     if (inwards)
10         e = e + 1;
11         iterate = e <= 5 && d + e <= b * street_length - STREET_INTERSECTION +
            inwards_gap && ...
12         street_inwards(c,d+e) == EMPTY_STREET; %STREET_INTERSECTION
            specifies the number of elements of the road inwards which will be taken
            care of by the crossroad/roundabout
13     else
14         e = e + 1;
15         %if gap is bigger than distance to edge, connect
16         %streets
17         if ( d + e > b * street_length)
18             %testing position in new street
19             hh = d + e - b * street_length;
20             %connect to next street
21             [ec,ed]=connection(a,b,c,hh, ...
22                 config_m, config_n, street_length);
23             while ( street_inwards(ec,ed) == EMPTY_STREET && e <= 5 )
24                 e = e + 1;
25                 %testing position in new street
26                 hh = d + e - b * street_length;
27                 %connect to next street
28                 [ec,ed]=connection(a,b,c,hh, ...
29                     config_m, config_n, street_length);
30             end
31             iterate = 0;
32         else
33             iterate = e <= 5 && street_outwards(c,d+e) == EMPTY_STREET; %% <= 4 b
                .c. it'll be 5 after this loop

```

```

34         end
35     end
36 end
37 gap = e - 1;
38
39 end

```

Listing 5: connection.m

```

1 function [cNew,dNew] = connection(aOld,bOld,cOld,posNew,m,n,length)
2 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
3 %CONNECTION Deside to which street a certain street connects to
4 %
5 %INPUT:
6 %AOLD column index of intersection
7 %BOLD, row index of intersection
8 %COLD, column index in t of old position
9 %posNEW, position in new street
10 %M, number of columns in city map
11 %N, number of rows in city map
12 %LENGTH, Length of a street
13 %
14 %OUTPUT:
15 %CNEW, Column index in t of new position
16 %DNEW, Row index in t of new position
17 %
18 %A project by Marcel Arikan, Nuhro Ego and Ralf Kohrt in the GeSS course "Modelling
19 %and Simulation of Social Systems with MATLAB" at ETH Zurich.
20 %Fall 2012
21 %Matlab code is based on code from Bastian Buecheler and Tony Wood in the GeSS
   course "Modelling
22 %and Simulation of Social Systems with MATLAB" at ETH Zurich.
23 %Spring 2010
24 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
25
26 %street heading up from intersection
27 if ( mod(cOld,4) == 1 )
28     %if there is a intersections above, connect to it
29     if ( aOld > 1 )
30         cNew = (aOld - 2) * 4 + 3;
31         dNew = (bOld - 1) * length + posNew;
32     %otherwise connect to other side of map
33     else
34         cNew = (m - 1) * 4 + 3;
35         dNew = (bOld - 1) * length + posNew;
36     end
37 end
38
39 %street heading left from intersection
40 if ( mod(cOld,4) == 2 )
41     %if there is a intersection to the left , connect to it
42     if ( bOld > 1 )
43         cNew = aOld * 4;
44         dNew = (bOld - 2) * length + posNew;
45     %otherwise connect to other side of map
46     else
47         cNew = aOld * 4;
48         dNew = (n - 1) * length + posNew;

```

```

49     end
50 end
51
52 %street heading down from intersection
53 if ( mod(cOld,4) == 3 )
54     %if there is a intersection below, connect to it
55     if ( aOld < m )
56         cNew = aOld * 4 + 1;
57         dNew = (bOld - 1) * length + posNew;
58     %otherwise connect to other side of map
59     else
60         cNew = 1;
61         dNew = (bOld - 1) * length + posNew;
62     end
63 end
64
65 %street heading right from intersection
66 if ( mod(cOld,4) == 0 )
67     %if there is a intersection to the right, connect to it
68     if ( bOld < n )
69         cNew = (aOld - 1) * 4 + 2;
70         dNew = bOld * length + posNew;
71     %otherwise connect to other side of map
72     else
73         cNew = (aOld - 1) * 4 + 2;
74         dNew = posNew;
75     end
76 end

```

Listing 6: pdestination.m

```

1 function [pfirst] = pdestination
2 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
3 %PDESTINATION Deside where a car is going
4 %
5 %OUTPUT:
6 %PFIRST = 0.1 car turns right
7 %         = 0.4 car goes straight ahead
8 %         = 0.7 car turns left
9 %
10 %A project by Marcel Arikan, Nuhro Ego and Ralf Kohrt in the GeSS course "Modelling
11 %and Simulation of Social Systems with MATLAB" at ETH Zurich.
12 %Fall 2012
13 %Matlab code is based on code from Bastian Buecheler and Tony Wood in the GeSS
14 %course "Modelling
15 %and Simulation of Social Systems with MATLAB" at ETH Zurich.
16 %Spring 2010
17 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
18 %decide which direction car is going
19 u = randi(12,1);
20 %probabilty 6/12 car goes straight ahead
21 if ( u <= 6 )
22     pfirst = 0.4;
23 end
24 %probabilty 3/12 car turns right
25 if ( u >= 7 && u <= 9 )
26     %indicate right

```

```

27 | pfirst = 0.7;
28 | end
29 | %probability 3/12 car turns left
30 | if ( u >= 10 && u <= 12 )
31 |     pfirst = 0.1;
32 | end
33 |
34 | end

```

Listing 7: schreckenberg.m

```

1 | function [ speed ] = schreckenberg(speed, gap, dawdleProb)
2 | %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
3 | %SCHRECKENBERG Nagel-Schreckenberg-Model
4 | %
5 | %OUTPUT: new speed of the selected car
6 | %
7 | %A project by Marcel Arikan, Nuhro Ego and Ralf Kohrt in the GeSS course "Modelling
8 | %and Simulation of Social Systems with MATLAB" at ETH Zurich.
9 | %Fall 2012
10 | %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
11 |
12 | %NS 1. step: increase velocity if < 5
13 | if ( speed < 5)
14 |     speed = speed + 1;
15 | end
16 |
17 | %NS 2. step: adapt speed to gap
18 | %reduce speed if gap is too small
19 | if ( speed > gap )
20 |     speed = gap;
21 | end
22 |
23 | %NS 3. step: dawdle
24 | if ( rand < dawdleProb && speed ~= 0 )
25 |     speed = speed - 1;
26 | end
27 |
28 | end

```

Listing 8: roundabout.m

```

1 | function [street_inwards_next, ...
2 |     inwards_speed_next, ...
3 |     street_outwards_next, ...
4 |     outwards_speed_next, ...
5 |     street_roundabout_local_next, ...
6 |     roundabout_speedlocal_next, ...
7 |     roundabout_exit_local_next, ...
8 |     pedestrian_bucket, inwards_gaps] ...
9 | = roundabout(street_inwards, ...
10 | inwards_speed, ...
11 | street_outwards, ...
12 | outwards_speed, ...
13 | street_roundabout, ...
14 | roundabout_exit, pedestrian_bucket, ...
15 | inwards_gaps, dawdleProb, ...

```

```

16     pedestrian_density , ...
17     street_inwards_next , ...
18     inwards_speed_next , ...
19     street_outwards_next , ...
20     outwards_speed_next , EMPTY_STREET, CAR, CAR_NEXT_EXIT, PEDESTRIAN,
        STREET_INTERSECTION, pahead)
21 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
22 %ROUNDABOUT Calculation of update for a certain roundabout, density and
23 %time step
24 %
25 %A project by Marcel Arikan, Nuhro Ego and Ralf Kohrt in the GeSS course "Modelling
26 %and Simulation of Social Systems with MATLAB" at ETH Zurich.
27 %Fall 2012
28 %Matlab code is based on code from Bastian Buecheler and Tony Wood in the GeSS
        course "Modelling
29 %and Simulation of Social Systems with MATLAB" at ETH Zurich.
30 %Spring 2010
31 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
32
33 %clear local next variables
34 street_roundabout_local_next = ones(1,12)*EMPTY_STREET;
35 roundabout_speedlocal_next = zeros(1,12);
36 roundabout_exit_local_next = zeros(1,12);
37
38 temp_roundabout_pedestrian_bucket = pedestrian_bucket;
39
40 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
41 %car in front of roundabout
42
43 for k = 1:4
44     if ( street_inwards(k,STREET_INTERSECTION+1) == CAR )
45         %entering roundabout with velocity 1 when possible
46         %roundabout position index
47         iR = mod(3*k+1,12);
48         % enter roundabout if car at position k*3 is about to exit and
49         % there is no car at position 3*k+1
50         if ( roundabout_exit(k*3) <= 1 && street_roundabout(iR) == EMPTY_STREET )
51             %enter roundabout
52             %decide which exit car is going to take
53             u = rand(1);
54             %if it takes 1. exit
55             if ( u <= (0.95/2*(1-pahead)) )
56                 roundabout_exit_local_next(iR) = 1;
57                 %indicate
58                 street_roundabout_local_next(iR) = CAR_NEXT_EXIT;
59                 roundabout_speedlocal_next(iR) = 1;
60             %if it takes 2. exit
61             elseif ( u <= (0.95/2*(1+pahead)) )
62                 roundabout_exit_local_next(iR) = 2;
63                 street_roundabout_local_next(iR) = CAR;
64                 roundabout_speedlocal_next(iR) = 1;
65             %if it takes 3. exit
66             elseif ( u <= 0.95 )
67                 roundabout_exit_local_next(iR) = 3;
68                 street_roundabout_local_next(iR) = CAR;
69                 roundabout_speedlocal_next(iR) = 1;
70             %if it takes 4. exit (turns around)
71             else

```

```

72         roundabout_exit_local_next(iR) = 4;
73         street_roundabout_local_next(iR) = CAR;
74         roundabout_speedlocal_next(iR) = 1;
75     end
76
77     %car waiting in front of roundabout
78     else
79         street_inwards_next(k,STREET_INTERSECTION+1) = street_inwards(k,
80             STREET_INTERSECTION+1);
81         inwards_speed_next(k,STREET_INTERSECTION+1) = 0;
82     end
83 end
84
85 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
86 %pedestrians
87
88
89 for k = 1:4
90     r = rand(1);
91     if (( street_inwards(k,STREET_INTERSECTION) == EMPTY_STREET || street_inwards(k,
92         STREET_INTERSECTION) == PEDESTRIAN) && ...
93         (r <= pedestrian_density || pedestrian_bucket(1,k) > 0))
94         street_inwards_next(k,STREET_INTERSECTION) = PEDESTRIAN;
95         inwards_speed_next(k,STREET_INTERSECTION) = 0;
96         if(r <= pedestrian_density)
97             temp_roundabout_pedestrian_bucket(2,k) = 1;
98         end
99         if(pedestrian_bucket(1,k) > 0)
100             temp_roundabout_pedestrian_bucket(1,k) = 0;
101         end
102     end
103     r = rand(1);
104     if (( street_outwards(k,2) == EMPTY_STREET || street_outwards(k,2) == PEDESTRIAN
105         ) && ...
106         (r <= pedestrian_density || pedestrian_bucket(2,k) > 0))
107         street_outwards_next(k,2) = PEDESTRIAN;
108         outwards_speed_next(k,2) = 0;
109         if(r <= pedestrian_density)
110             temp_roundabout_pedestrian_bucket(1,k) = 1;
111         end
112         if(pedestrian_bucket(2,k) > 0)
113             temp_roundabout_pedestrian_bucket(2,k) = 0;
114         end
115     end
116     if(0)
117         if (( street_roundabout(k*3-1) == EMPTY_STREET || street_roundabout(k*3-1)
118             == PEDESTRIAN) && roundabout_pedestrian_bucket(k) > 0)
119             street_roundabout_local_next(k*3-1) = PEDESTRIAN;
120             roundabout_speedlocal_next(k*3-1) = 0;
121             roundabout_exit_local_next(k*3-1) = 0;
122             if(roundabout_pedestrian_bucket(k) >= 1)
123                 roundabout_pedestrian_bucket(k) = roundabout_pedestrian_bucket(k)-1;
124             end
125         elseif ( street_inwards(k,2) == PEDESTRIAN && roundabout_pedestrian_bucket(k)
126             == 0)
127             street_roundabout_local_next(k*3-1) = EMPTY_STREET;
128             roundabout_speedlocal_next(k*3-1) = 0;

```

```

125         roundabout_exit_local_next(k*3-1) = 0;
126     end
127 end
128 end
129
130 pedestrian_bucket = temp_roundabout_pedestrian_bucket;
131 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
132 %car outside roundabout
133
134
135
136 for k = 1:4
137     for j = 1:STREET_INTERSECTION
138         e = 1;
139         while (e <= 5 && ((street_outwards(k,j+e) == EMPTY_STREET &&
140             street_outwards_next(k,j+e) == EMPTY_STREET) || ...
141             (street_outwards(k,j+e) == PEDESTRIAN && street_outwards_next(k,
142                 j+e) == EMPTY_STREET) ))
143             e = e + 1;
144         end
145         gap = e - 1;
146         v = schreckenberg(outwards_speed(k,j), gap, dawdleProb);
147         if(street_outwards(k,j) == CAR)
148             if ( (street_outwards(k,j+v) == EMPTY_STREET && street_outwards_next(k,j
149                 +v) == EMPTY_STREET) || ...
150                 (street_outwards(k,j+v) == PEDESTRIAN && street_outwards_next(k,
151                     j+v) == EMPTY_STREET) )
152                 street_outwards_next(k,j+v) = CAR;
153                 outwards_speed_next(k,j+v) = v;
154             else
155                 street_outwards_next(k,j) = CAR;
156                 outwards_speed_next(k,j) = 0;
157             end
158         end
159         e = 1;
160         while (e <= 5 && j + e <= STREET_INTERSECTION+1 && ((street_inwards(k,j+e)
161             == EMPTY_STREET && street_inwards_next(k,j+e) == EMPTY_STREET) || ...
162             ( street_inwards(k,j+e) == PEDESTRIAN && street_inwards_next(k,j
163                 +e) == EMPTY_STREET) ))
164             e = e + 1;
165         end
166         gap = e - 1;
167         v = schreckenberg(inwards_speed(k,j), gap, dawdleProb);
168         if(j == 1)
169             inwards_gaps(1,k) = gap;
170         end
171         if(street_inwards(k,j) == CAR)
172             if ( ( street_inwards(k,j+v) == EMPTY_STREET && street_inwards_next(k,j+
173                 v) == EMPTY_STREET) || ...
174                 ( street_inwards(k,j+v) == PEDESTRIAN && street_inwards_next(k,j
175                     +v) == EMPTY_STREET) )
176                 street_inwards_next(k,j+v) = CAR;
177                 inwards_speed_next(k,j+v) = v;
178             else
179                 street_inwards_next(k,j) = CAR;
180                 inwards_speed_next(k,j) = 0;
181             end
182         end
183     end
184 end

```

```

175     end
176 end
177
178
179
180 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
181 %car in roundabout
182
183 for j = 1:12
184     if ( street_roundabout(j) == CAR || street_roundabout(j) == CAR_NEXT.EXIT )
185
186         %cars in roundabout not at an exit
187         if (mod(j,3) ~= 0 )
188             %if space free, move one forward
189             if ( street_roundabout(j+1) == EMPTY_STREET &&
190                 street_roundabout_local_next(j+1) == EMPTY_STREET)
191                 %take new position
192                 street_roundabout_local_next(j+1) = street_roundabout(j);
193                 roundabout_speedlocal_next(j+1) = 1;
194                 roundabout_exit_local_next(j+1) = roundabout_exit(j);
195             %if no space free, stay
196             else
197                 street_roundabout_local_next(j) = street_roundabout(j);
198                 roundabout_speedlocal_next(j) = 0;
199                 roundabout_exit_local_next(j) = roundabout_exit(j);
200             end
201
202             %car at an exit
203             else
204
205                 %if car is at its exit
206                 if ( roundabout_exit(j) == 1 )
207                     %if space free, leave roundabout
208                     if ( street_outwards(j/3,1) == EMPTY_STREET )
209                         street_outwards_next(j/3,1) = CAR;
210                         outwards_speed_next(j/3,1) = 1;
211                     %if no space free, stay
212                     else
213                         street_roundabout_local_next(j) = street_roundabout(j);
214                         roundabout_speedlocal_next(j) = 0;
215                         roundabout_exit_local_next(j) = roundabout_exit(j);
216                     end
217
218                 %car at an exit but not the one its taking
219                 else
220                     %connect street_roundabout(12) with street_roundabout(1)
221                     if ( j == 12 )
222                         j1 = 1;
223                     else
224                         j1 = j+1;
225                     end
226                     %if space free, move one forward and decrease exit
227                     %counter
228                     if ( street_roundabout(j1) == EMPTY_STREET )
229                         %decrease exit by one
230                         roundabout_exit_local_next(j1) = roundabout_exit(j) - 1;
231                         roundabout_speedlocal_next(j1) = 1;
232                     if ( roundabout_exit_local_next(j1) == 1 )

```



```

232         %indicate
233         street_roundabout_local_next(j1) = CAR_NEXT_EXIT;
234     else
235         street_roundabout_local_next(j1) = CAR;
236     end
237     %if no space free, stay
238     else
239         street_roundabout_local_next(j) = street_roundabout(j);
240         roundabout_speedlocal_next(j) = 0;
241         roundabout_exit_local_next(j) = roundabout_exit(j);
242     end
243 end
244 end
245 end
246 end
247
248 end

```

Listing 9: crosslight.m

```

1 function [street_inwards_next, ...
2     inwards_speed_next, ...
3     street_outwards_next, ...
4     outwards_speed_next, ...
5     street_crossroad_next, ...
6     crossroad_speed_next, ...
7     crossroad_exit_next, ...
8     pedestrian_bucket, inwards_gaps, ...
9     trace_left_next, trace_left_speed_next, trace_right_direction_next, trafficlight
10 ] ...
11 = crosslight(street_inwards, ...
12     inwards_speed, ...
13     street_outwards, ...
14     outwards_speed, ...
15     street_crossroad, ...
16     crossroad_speed, ...
17     crossroad_exit, pedestrian_bucket, ...
18     inwards_gaps, dawdleProb, ...
19     pedestrian_density, ...
20     street_inwards_next, ...
21     inwards_speed_next, ...
22     street_outwards_next, ...
23     outwards_speed_next, EMPTY_STREET, CAR, CAR_NEXT_EXIT, PEDESTRIAN,
24     STREET_INTERSECTION, ...
25     pahead, trace_left, trace_left_speed, trace_right_direction, ...
26     localphase, aheadphase, turnphase)
27 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
28 %CROSSLIGHT Calculation of update for a certain crossroad, including lane for cars
29 %turning left
30 %and 8 cells of street_inwards and street_outwards
31 %
32 %additional Output:
33 %inwards_gaps: gap to place car from street_inwards when entering the 8 cells in
34 %front of
35 %crossroad calculated by crosslight
36 %trafficlight: signalisation for every lane to plot traffic lights in
37 %display
38 %

```

```

35 %additional INPUT:
36 %pahead: probabilitiy for car driving ahead
37 %localphase: signalisation phase for this crossroad
38 %aheadphase, turnphaae: relative time for signalisation staying green for
39 %car turning or driving ahead
40 %
41 %This program requires the following subprogams:
42 %settraffilight
43 %crosslight_measure_gap
44 %crosslight_next_ij
45 %schreckenber
46 %pdestination
47 %
48 %A project by Marcel Arian, Nuhro Ego and Ralf Kohrt in the GeSS course "Modelling
49 %and Simulation of Social Systems with MATLAB" at ETH Zurich.
50 %Fall 2012
51 %Matlab code is based on code from Bastian Buecheler and Tony Wood in the GeSS
    course "Modelling
52 %and Simulation of Social Systems with MATLAB" at ETH Zurich.
53 %Spring 2010
54 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
55
56 NO_EXIT_YET = 0;
57 EXIT_LEFT = 5;
58 EXIT_RIGHT = 6;
59 EXIT_STRAIGHT_TOP = 3;
60 EXIT_STRAIGHT_LEFT = 4;
61 EXIT_STRAIGHT_BOTTOM = 1;
62 EXIT_STRAIGHT_RIGHT = 2;
63
64 %clear local next variables
65 street_crossroad_next = ones(6,6)*EMPTY_STREET;
66 crossroad_speed_next = zeros(6,6);
67 crossroad_exit_next = zeros(6,6);
68 trace_left_next = ones(4,8)*EMPTY_STREET;
69 trace_left_speed_next = zeros(4,8);
70 trace_right_direction_next = ones(4,8)*NO_EXIT_YET;
71
72 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
73 %set traffic light
74 %trafficlight = zeros(12,1) 0=red for car and pedestrians
75 trafficlight = settraffilight(localphase, aheadphase, turnphase, pedestrian_density
    );
76 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
77 %place randomly pedestrians
78 for k = 1:4
79     if (rand(1) <= pedestrian_density )
80         pedestrian_bucket(2,k) = 1;    %use bucket to make sure that pedestrians
            accumulate during redphase
81     end
82     if (( street_outwards(k,2) == EMPTY_STREET || street_outwards(k,2) == PEDESTRIAN
        ) && ...
83         pedestrian_bucket(2,k) > 0 && trafficlight(1+(k-1)*3,1)==1 )
84         street_outwards_next(k,2) = PEDESTRIAN;
85         outwards_speed_next(k,2) = 0;
86         pedestrian_bucket(2,k) = 0;
87     elseif ( street_outwards(k,2) == PEDESTRIAN)
88         street_outwards_next(k,2) = EMPTY_STREET;

```

```

89         outwards_speed_next(k,2) = 0;
90     end
91 end
92
93 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
94 %car in front of crossroad and initializing direction
95
96 for k = 1:4
97     for l=1:STREET.INTERSECTION+1
98         %initializing randomly directions
99         if (street_inwards(k,l) == CAR && trace_right_direction(k,l)==NO_EXIT_YET)
100             u=rand(1);
101             %if it goes left
102             if ( u < ((1-pahead)/2))
103                 trace_right_direction(k,l) = EXIT_LEFT;
104                 %if it goes ahead
105             elseif ( u <= ((1+pahead)/2))
106                 trace_right_direction(k,l) = k;
107
108                 %if it goes right
109             else
110                 trace_right_direction(k,l) = EXIT_RIGHT;
111
112             end
113         end
114
115         %take cars with EXIT_LEFT waiting into trace_left if space is free
116         if (street_inwards(k,l) == CAR && trace_right_direction(k,l)==EXIT_LEFT)
117             if (trace_left(k,l) == EMPTY_STREET)
118                 trace_left_next(k,l) = CAR;
119                 trace_left_speed_next(k,l) = inwards_speed(k,l);
120             else
121                 street_inwards_next(k,l) = CAR;
122                 inwards_speed_next(k,l) = 0;
123                 trace_right_direction_next(k,l)=EXIT_LEFT;
124             end
125         end
126
127         %inwards
128         if (street_inwards(k,l) == CAR && trace_right_direction(k,l)~=EXIT_LEFT)
129             gap = crosslight_measure_gap(-k, l, trace_right_direction(k,l) ,
130                 street_crossroad , ...
131                 street_outwards, street_outwards_next, l, street_inwards,
132                 street_inwards_next, trafficlight(3*k,l), ...
133                 EXIT_LEFT,EXIT_RIGHT,EXIT_STRAIGHT_TOP,EXIT_STRAIGHT_LEFT,
134                 EXIT_STRAIGHT_BOTTOM,EXIT_STRAIGHT_RIGHT, STREET.INTERSECTION,
135                 EMPTY_STREET);
136             v = schreckenberg(inwards_speed(k,l),gap,dawdleProb);
137             if (l == 1)
138                 inwards_gaps(1,k) = gap;
139             end
140             if (l+v<=STREET.INTERSECTION+1) %not yet entering crossroad
141                 street_inwards_next(k,l+v) = CAR;
142                 inwards_speed_next(k,l+v) = v;
143                 trace_right_direction_next(k,l+v) = trace_right_direction(k,l);
144             else
145                 ni = -k; %minus indices for
146                 crosslight_measure_gap

```

```

142     nj = STREET_INTERSECTION+1;
143     q = 1;
144     while (q <= l+v-(STREET_INTERSECTION+1))
145         if (ni > 0 || nj == STREET_INTERSECTION+1)
146             [ni, nj] = crosslight_next_ij(ni, nj, trace_right_direction(
147                 k, l), ...
148                 EXIT_LEFT, EXIT_RIGHT, EXIT_STRAIGHT_TOP,
149                 EXIT_STRAIGHT_LEFT, EXIT_STRAIGHT_BOTTOM,
150                 EXIT_STRAIGHT_RIGHT);
151         else %we are already in street_outwards
152             nj = nj+1;
153         end
154         q = q+1;
155     end
156     if (ni > 0) %place car in crossroad
157         street_crossroad_next(ni, nj) = CAR;
158         crossroad_speed_next(ni, nj) = v;
159         crossroad_exit_next(ni, nj) = trace_right_direction(k, l);
160     else
161         street_outwards_next(-ni, nj) = CAR; %ni again minus ->
162         outside_crossroad
163         outwards_speed_next(-ni, nj) = v;
164     end
165 end
166 end
167
168 %trace_left
169 if (trace_left(k, l) == CAR)
170     gap = crosslight_measure_gap(-k, l, EXIT_LEFT, street_crossroad, ...
171         street_outwards, street_outwards_next, l, trace_left,
172         trace_left_next, trafficlight(2+3*(k-1), l), ...
173         EXIT_LEFT, EXIT_RIGHT, EXIT_STRAIGHT_TOP, EXIT_STRAIGHT_LEFT,
174         EXIT_STRAIGHT_BOTTOM, EXIT_STRAIGHT_RIGHT, STREET_INTERSECTION,
175         EMPTY_STREET);
176     v = schreckenberg(trace_left_speed(k, l), gap, dawdleProb);
177     if (l+v <= STREET_INTERSECTION+1)
178         trace_left_next(k, l+v) = CAR;
179         trace_left_speed_next(k, l+v) = v;
180     else
181         ni = -k;
182         nj = STREET_INTERSECTION+1;
183         q = 1;
184         while (q <= l+v-(STREET_INTERSECTION+1))
185             if (ni > 0 || nj == STREET_INTERSECTION+1)
186                 [ni, nj] = crosslight_next_ij(ni, nj, EXIT_LEFT, ...
187                     EXIT_LEFT, EXIT_RIGHT, EXIT_STRAIGHT_TOP,
188                     EXIT_STRAIGHT_LEFT, EXIT_STRAIGHT_BOTTOM,
189                     EXIT_STRAIGHT_RIGHT);
190             else %we are already in street_outwards
191                 nj = nj+1;
192             end
193             q = q+1;
194         end
195         if (ni > 0)
196             street_crossroad_next(ni, nj) = CAR;
197             crossroad_speed_next(ni, nj) = v;
198             crossroad_exit_next(ni, nj) = EXIT_LEFT;
199         else

```

```

191         street_outwards_next(-ni,nj) = CAR;
192         outwards_speed_next(-ni,nj) = v;
193     end
194 end
195 end
196 end
197 end
198
199 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
200 %car in crossroad
201
202 for i = 1:6
203     for j = 1:6
204         if (street_crossroad(i,j) == CAR)
205             gap = crosslight_measure_gap(i, j, crossroad_exit(i,j), street_crossroad,
206                 ...
207                 street_outwards, street_outwards_next, 0, street_inwards,
208                 street_inwards_next, trafficlight(1+3*(k-1),1), ...
209                 EXIT_LEFT,EXIT_RIGHT,EXIT_STRAIGHT_TOP,EXIT_STRAIGHT_LEFT,
210                 EXIT_STRAIGHT_BOTTOM,EXIT_STRAIGHT_RIGHT, STREET_INTERSECTION,
211                 EMPTY_STREET);
212             v = schreckenberg(crossroad_speed(i,j),gap,dawdleProb);
213             ni = i;
214             nj = j;
215             q = 1;
216             while(q <= v)
217                 if(ni > 0)
218                     [ni, nj] = crosslight_next_ij(ni, nj, crossroad_exit(i,j), ...
219                         EXIT_LEFT,EXIT_RIGHT,EXIT_STRAIGHT_TOP,EXIT_STRAIGHT_LEFT,
220                         EXIT_STRAIGHT_BOTTOM,EXIT_STRAIGHT_RIGHT);
221                 else %we are already in street_outwards
222                     nj = nj+1;
223                 end
224                 q = q+1;
225             end
226             if (ni > 0)
227                 street_crossroad_next(ni,nj) = CAR;
228                 crossroad_speed_next(ni,nj) = v;
229                 crossroad_exit_next(ni,nj) = crossroad_exit(i,j);
230             else
231                 street_outwards_next(-ni,nj) = CAR;
232                 outwards_speed_next(-ni,nj) = v;
233             end
234         end
235     end
236 end
237
238 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
239 %car outwards
240
241 for k = 1:4
242     for l = 1:STREET_INTERSECTION
243         %outwards street
244         e = 1;
245         while (e <= 5 && street_outwards(k,l+e) == EMPTY_STREET &&
246             street_outwards_next(k,l+e) == EMPTY_STREET)
247             e = e + 1;
248         end

```

```

243     gap = e - 1;
244     v = schreckenberg(outwards_speed(k,l), gap, dawdleProb);
245     if (street_outwards(k,l) == CAR)
246         street_outwards_next(k,l+v) = CAR;
247         outwards_speed_next(k,l+v) = v;
248     end
249 end
250 end
251
252 end

```

Listing 10: crosslight-measure-gap.m

```

1 function [ gap ] = crosslight_measure_gap(i, j, direction, street_crossroad, ...
2     street_outwards, street_outwards_next, inwards, street_inwards,
3     street_inwards_next, traffic_light, ...
4     EXIT_LEFT, EXIT_RIGHT, EXIT_STRAIGHT_TOP, EXIT_STRAIGHT_LEFT, EXIT_STRAIGHT_BOTTOM,
5     EXIT_STRAIGHT_RIGHT, STREET_INTERSECTION, EMPTY_STREET)
6 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
7 %crosslight_measure_gap this function will measure the gap to the next car
8 %in a crosslight
9 %
10 %A project by Marcel Arikan, Nuhro Ego and Ralf Kohrt in the GeSS course "Modelling
11 %and Simulation of Social Systems with MATLAB" at ETH Zurich.
12 %Fall 2012
13 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
14
15 e = 1;
16 iterate = 1;
17 ni = i;
18 nj = j;
19 while (e <= 5 && iterate)
20     if ((ni < 0 && nj == STREET_INTERSECTION+1 && inwards) || ni > 0)
21         [ni, nj] = crosslight_next_ij(ni, nj, direction, ...
22             EXIT_LEFT, EXIT_RIGHT, EXIT_STRAIGHT_TOP, EXIT_STRAIGHT_LEFT,
23             EXIT_STRAIGHT_BOTTOM, EXIT_STRAIGHT_RIGHT);
24     else
25         %ni = ni;
26         nj = nj+1;
27     end
28     if (ni > 0)
29         inwards = 0;
30         if (street_crossroad(ni, nj) == EMPTY_STREET)
31             e = e + 1;
32         else
33             iterate = 0;
34         end
35         if ((direction == EXIT_LEFT || direction == EXIT_RIGHT) && e > 2) %limit
36             speed inside the crossection
37             e = 2;
38             iterate = 0;
39         end
40     else
41         if (inwards)
42             if (nj == STREET_INTERSECTION+1 || nj == STREET_INTERSECTION) %last or
43                 second to last field in front of intersection have to wait if
44                 traffic light is red

```

```

39         if(traffic_light && street_inwards(-ni,nj) == EMPTY_STREET &&
40            street_inwards_next(-ni,nj) == EMPTY_STREET) %% traffic_light
41                green and street empty
42                e = e + 1;
43            else
44                iterate = 0;
45            end
46        else
47            if(street_inwards(-ni,nj) == EMPTY_STREET && street_inwards_next(-ni,
48                nj) == EMPTY_STREET)
49                e = e + 1;
50            else
51                iterate = 0;
52            end
53        end
54    else
55        if(street_outwards(-ni,nj) == EMPTY_STREET && street_outwards_next(-ni,
56            nj) == EMPTY_STREET)
57            e = e + 1;
58        else
59            iterate = 0;
60        end
61    end
62 end
end
gap = e - 1;
end

```

Listing 11: crosslight-next-ij.m

```

1 function [ ni, nj ] = crosslight_next_ij(i, j, direction, EXIT_LEFT, EXIT_RIGHT,
2     EXIT_STRAIGHT_TOP, EXIT_STRAIGHT_LEFT, EXIT_STRAIGHT_BOTTOM, EXIT_STRAIGHT_RIGHT)
3 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
4 %crosslight_next_ij this function will return the next value for i and j
5 %which a car with a given direction and i j coordinates will have
6 %
7 %A project by Marcel Arikan, Nuhro Ego and Ralf Kohrt in the GeSS course "Modelling
8 %and Simulation of Social Systems with MATLAB" at ETH Zurich.
9 %Fall 2012
10 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
11 switch(direction)
12     case EXIT_LEFT
13         if(i == 1 && j == 3)
14             ni = 2;
15             nj = 3;
16         elseif(i == 2 && j == 3)
17             ni = 3;
18             nj = 4;
19         elseif(i == 3 && j == 4)
20             ni = 4;
21             nj = 5;
22         elseif(i == 4 && j == 5)
23             ni = 5;
24             nj = 6;
25         elseif(i == 5 && j == 6)
26             ni = -4;

```

```

27         nj = 1;
28     elseif(i == 4 && j == 1)
29         ni = 4;
30         nj = 2;
31     elseif(i == 4 && j == 2)
32         ni = 3;
33         nj = 3;
34     elseif(i == 3 && j == 3)
35         ni = 2;
36         nj = 4;
37     elseif(i == 2 && j == 4)
38         ni = 1;
39         nj = 5;
40     elseif(i == 1 && j == 5)
41         ni = -1;
42         nj = 1;
43     elseif(i == 6 && j == 4)
44         ni = 5;
45         nj = 4;
46     elseif(i == 5 && j == 4)
47         ni = 4;
48         nj = 3;
49     elseif(i == 4 && j == 3)
50         ni = 3;
51         nj = 2;
52     elseif(i == 3 && j == 2)
53         ni = 2;
54         nj = 1;
55     elseif(i == 2 && j == 1)
56         ni = -2;
57         nj = 1;
58     elseif(i == 3 && j == 6)
59         ni = 3;
60         nj = 5;
61     elseif(i == 3 && j == 5)
62         ni = 4;
63         nj = 4;
64     elseif(i == 4 && j == 4)
65         ni = 5;
66         nj = 3;
67     elseif(i == 5 && j == 3)
68         ni = 6;
69         nj = 2;
70     elseif(i == 6 && j == 2)
71         ni = -3;
72         nj = 1;
73     elseif(i < 0)    %here I assume the car is in the last position of the
                        inwards street
74         if(i == -1)
75             ni = 1;
76             nj = 3;
77         elseif(i == -2)
78             ni = 4;
79             nj = 1;
80         elseif(i == -3)
81             ni = 6;
82             nj = 4;
83         elseif(i == -4)

```



```

84         ni = 3;
85         nj = 6;
86     end
87 end
88 case EXIT_RIGHT
89     if(i == 1)
90         if(j == 1)
91             ni = -2;
92             nj = 1;
93         else
94             ni = -1;
95             nj = 1;
96         end
97     elseif(i == 6)
98         if(j == 1)
99             ni = -3;
100            nj = 1;
101        else
102            ni = -4;
103            nj = 1;
104        end
105    elseif(i == -1)
106        ni = 1;
107        nj = 1;
108    elseif(i == -2)
109        ni = 6;
110        nj = 1;
111    elseif(i == -3)
112        ni = 6;
113        nj = 6;
114    elseif(i == -4)
115        ni = 1;
116        nj = 6;
117    end
118 case EXIT_STRAIGHT_TOP
119     if(i > 0)
120         nj = j;
121         ni = i-1;
122         if(ni < 1)
123             ni = -EXIT_STRAIGHT_BOTTOM;
124             nj = 1;
125         end
126     elseif(i == -EXIT_STRAIGHT_TOP) %%check if it comes from BOTTOM
127         nj = 5;
128         ni = 6;
129     else
130         ni = i;
131         nj = j+1;
132     end
133 case EXIT_STRAIGHT_BOTTOM
134     if(i > 0)
135         nj = j;
136         ni = i+1;
137         if(ni > 6)
138             ni = -EXIT_STRAIGHT_TOP;
139             nj = 1;
140         end
141     elseif(i == -EXIT_STRAIGHT_BOTTOM)

```

```

142         nj = 2;
143         ni = 1;
144     else
145         ni = i;
146         nj = j+1;
147     end
148     case EXIT_STRAIGHT_LEFT
149         if(i > 0)
150             nj = j-1;
151             ni = i;
152             if(nj < 1)
153                 ni = -2;
154                 nj = 1;
155             end
156             elseif(i == -4)
157                 nj = 6;
158                 ni = 2;
159             else
160                 ni = i;
161                 nj = j+1;
162             end
163     case EXIT_STRAIGHT_RIGHT
164         if(i > 0)
165             nj = j+1;
166             ni = i;
167             if(nj > 6)
168                 ni = -4;
169                 nj = 1;
170             end
171             elseif(i == -2)
172                 nj = 1;
173                 ni = 5;
174             else
175                 ni = i;
176                 nj = j+1;
177             end
178     otherwise
179         display(direction);
180         display(i);
181         display(j);
182         ni = 0;
183         nj = 0;
184 end
185
186 end

```

Listing 12: plotresults.m

```

1 function plotresults(d, pd, folder)
2 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
3 %TRAFFIC Simulation of traffic in an city map containing roundabouts and
4 %crossroads.
5 %
6 %This function will plot the precalculated results which are stored in
7 %results/folder where folder is the variable supplied from above
8 %
9 %INPUTS:
10 %D is the car density you want to plot over (should be a vector, else the

```

```

11 %plot would only show one point
12 %PD is the pedestrian density
13 %folder is the folder your data is located, this should be an integer!!
14 %
15 %A project by Marcel Arikan, Nuhro Ego and Ralf Kohrt in the GeSS course "Modelling
16 %and Simulation of Social Systems with MATLAB" at ETH Zurich.
17 %Fall 2012
18 %Matlab code is based on code from Bastian Buecheler and Tony Wood in the GeSS
19 %course "Modelling
20 %and Simulation of Social Systems with MATLAB" at ETH Zurich.
21 %Spring 2010
22 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
23 close all;
24
25 %%% runtime measurement - start
26 tic;
27
28 filename = sprintf(' ../ results/%g/config.mat', folder);
29 load(filename, 'c', 'pahead');
30
31
32 [c_m,c_n] = size(c);
33 %check if city map is a mix of crossroads and roundabouts or if it is made up
34 %purely of one or the other
35 mix = not( sum(sum(c)) == c_m * c_n || sum(sum(c)) == 0 );
36
37 %average flow and distributions for every density supplied
38 avFlow = zeros(max(size(pd)),max(size(d)));
39 avRo = zeros(max(size(pd)),max(size(d)));
40 avCr = zeros(max(size(pd)),max(size(d)));
41 avSpeed = zeros(max(size(pd)),max(size(d)));
42
43 for di=1:max(size(d))
44     for pdi=1:max(size(pd))
45         [config_m,config_n] = size(c);
46         filename = sprintf(' ../ results/%g/result_(%g x %g)_%g_%g.mat', folder, ...
47             config_m, config_n, d(di), pd(pdi));
48         if exist(filename, 'file')
49             disp(filename);
50             load(filename, 'result');
51             disp(result);
52             avFlow(pdi,di) = result(1);
53             avRo(pdi,di) = result(2);
54             avCr(pdi,di) = result(3);
55             avSpeed(pdi,di) = result(4);
56         end
57     end
58 end
59
60 fig2 = figure(2);
61 %is city map is a mix of roundabout and crossroads, plot distribution
62 if ( mix )
63     %plot relative number of cars at roundabouts and number of cars at
64     %crossroads versus traffic density
65     subplot(2,1,2);
66     plot(d,avRo*100,'rx',d,avCr*100,'gx');
67     set(gca, 'FontSize',16);

```

```

68     title('Traffic Distribution');
69     xlabel('traffic density');
70     ylabel('relative number of cars [%]');
71     legend('around roundabouts','around crossroads');
72     ylim([0 100]);
73     subplot(2,1,1);
74 end
75
76 %plot traffic flow versus traffic density
77 hold on;
78 % size(avFlow)
79 for i=1:length(pd)
80     pd(i);
81     avFlow_pdi = avFlow(i,:);
82     plot(d,avFlow_pdi, '-x');
83 end
84 % plot(d,avFlow(:,:),'-o')
85 set(gca,'FontSize',16);
86 title('Traffic Dynamics');
87 xlabel('traffic density');
88 ylabel('average traffic flow');
89 %ylim([0 0.5]);
90
91 fig3 = figure(3);
92 hold on;
93 for i=1:length(d)
94     d(i);
95     avFlow_di = avFlow(:,i);
96     plot(pd,avFlow_di, '-x');
97 end
98 % plot(pd,avFlow(:,:),'-o')
99 set(gca,'FontSize',16);
100 title('Traffic Dynamics');
101 xlabel('pedestrian density');
102 ylabel('average traffic flow');
103
104
105 fig4 = figure(4);
106 hold on;
107 for i=1:length(pd)
108     pd(i);
109     avSpeed_pdi = avSpeed(i,:);
110     plot(d,avSpeed_pdi, '-x');
111 end
112 set(gca,'FontSize',16);
113 title('Traffic Dynamics');
114 xlabel('traffic density');
115 ylabel('average speed');
116
117
118 fig5 = figure(5);
119 hold on;
120 for i=1:length(d)
121     d(i);
122     avSpeed_di = avSpeed(:,i);
123     plot(pd,avSpeed_di, '-x');
124 end
125 set(gca,'FontSize',16);

```

```

126 title('Traffic Dynamics');
127 xlabel('pedestrian density');
128 ylabel('average speed');
129
130 fig6 = figure(6);
131 surf(d,pd,avSpeed);
132 title('Traffic Dynamics','FontWeight','bold');
133 xlabel('traffic density');
134 ylabel('pedestrian density');
135 zlabel('average speed');
136
137
138 fig7 = figure(7);
139 surf(d,pd,avFlow);
140 title('Traffic Dynamics','FontWeight','bold');
141 xlabel('traffic density');
142 ylabel('pedestrian density');
143 zlabel('average traffic flow');
144
145
146
147
148 %%% runtime measurement - end
149 toc;
150
151 end

```

Listing 13: plot-map.m

```

1 function [map] = plot_map(street_length, config, car_density, display, ...
2     street_inwards, street_outwards, street_roundabout, street_crossroad, ...
3     BUILDING,EMPTY_STREET, light, trace_left, STREET_INTERSECTION)
4 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
5 %PLOT_MAP This function plots the map
6 %
7 %This program requires the following subprograms:
8 %none
9 %
10 %A project by Marcel Arikan, Nuhro Ego and Ralf Kohrt in the GeSS course "Modelling
11 %and Simulation of Social Systems with MATLAB" at ETH Zurich.
12 %Fall 2012
13 %Matlab code is based on code from Bastian Buecheler and Tony Wood in the GeSS
14 %course "Modelling
15 %and Simulation of Social Systems with MATLAB" at ETH Zurich.
16 %Spring 2010
17 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
18 %dimensions of config, how many intersections in x and y direction are there?
19 [config_m,config_n] = size(config);
20
21 %initialize map
22 map = zeros(config_m*(2*street_length+6),config_n*(2*street_length+6));
23 map(1,1)=2;
24
25 %iterate over all intersection
26 for a = 1:config_m
27     for b = 1:config_n
28

```

```

29 %define Index starting points for each intersection
30 tI_m = (a - 1) * 4;
31 tI_n = (b - 1) * street_length;
32 mapI_m = (a - 1) * (2 * street_length + 6);
33 mapI_n = (b - 1) * (2 * street_length + 6);
34
35
36 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
37 %write roundabout into map
38
39 %check if intersection is a roundabout
40 if ( config(a,b) == 0 )
41     %define index starting point for this roundabout
42     rI_n = (b - 1) * 12;
43     %write roundabout into map
44     map(mapI_m+street_length+1:mapI_m+street_length+6,...
45         mapI_n+street_length+1:mapI_n+street_length+6) = ...
46         [ BUILDING EMPTY_STREET street_roundabout(a,rI_n+4)
47           street_roundabout(a,rI_n+3) EMPTY_STREET BUILDING;
48           EMPTY_STREET street_roundabout(a,rI_n+5) EMPTY_STREET EMPTY_STREET
49           street_roundabout(a,rI_n+2) EMPTY_STREET;
50           street_roundabout(a,rI_n+6) EMPTY_STREET BUILDING BUILDING
51           EMPTY_STREET street_roundabout(a,rI_n+1);
52           street_roundabout(a,rI_n+7) EMPTY_STREET BUILDING BUILDING
53           EMPTY_STREET street_roundabout(a,rI_n+12);
54           EMPTY_STREET street_roundabout(a,rI_n+8) EMPTY_STREET EMPTY_STREET
55           street_roundabout(a,rI_n+11) EMPTY_STREET;
56           BUILDING EMPTY_STREET street_roundabout(a,rI_n+9) street_roundabout(
57             a,rI_n+10) EMPTY_STREET BUILDING];
58
59 %write streets into map
60 %normal street
61 for i = 1:street_length-3
62     map(mapI_m+i,mapI_n+street_length+2) = street_inwards(tI_m+1,tI_n+i)
63     ; % top , inwards
64     map(mapI_m+street_length+5,mapI_n+i) = street_inwards(tI_m+2,tI_n+i)
65     ; % left , inwards
66     map(mapI_m+2*street_length+7-i,mapI_n+street_length+5) =
67     street_inwards(tI_m+3,tI_n+i); % bottom , inwards
68     map(mapI_m+street_length+2,mapI_n+2*street_length+7-i) =
69     street_inwards(tI_m+4,tI_n+i); % right , inwards
70
71 end
72 for i = 1+3:street_length
73     map(mapI_m+street_length+1-i,mapI_n+street_length+5) =
74     street_outwards(tI_m+1,tI_n+i); % top , outwards
75     map(mapI_m+street_length+2,mapI_n+street_length+1-i) =
76     street_outwards(tI_m+2,tI_n+i); % left , outwards
77     map(mapI_m+street_length+6+i,mapI_n+street_length+2) =
78     street_outwards(tI_m+3,tI_n+i); % bottom , outwards
79     map(mapI_m+street_length+5,mapI_n+street_length+6+i) =
80     street_outwards(tI_m+4,tI_n+i); % right , outwards
81
82 end
83 %'last mile'
84 for i = street_length-3+1:street_length
85     map(mapI_m+i,mapI_n+street_length+3) = street_inwards(tI_m+1,tI_n+i)
86     ; % top , inwards
87     map(mapI_m+street_length+4,mapI_n+i) = street_inwards(tI_m+2,tI_n+i)
88     ; % left , inwards

```

```

71         map(mapI_m+2*street_length+7-i, mapI_n+street_length+4) =
72             street_inwards(tI_m+3, tI_n+i); % bottom, inwards
73     end
74     for i = 1:3
75         map(mapI_m+street_length+1-i, mapI_n+street_length+4) =
76             street_outwards(tI_m+1, tI_n+i); % top, outwards
77         map(mapI_m+street_length+3, mapI_n+street_length+1-i) =
78             street_outwards(tI_m+2, tI_n+i); % left, outwards
79         map(mapI_m+street_length+6+i, mapI_n+street_length+3) =
80             street_outwards(tI_m+3, tI_n+i); % bottom, outwards
81         map(mapI_m+street_length+4, mapI_n+street_length+6+i) =
82             street_outwards(tI_m+4, tI_n+i); % right, outwards
83     end
84     %filling fields for optics
85     map(mapI_m+street_length+1-4, mapI_n+street_length+3) = EMPTY_STREET;
86     % top, left
87     map(mapI_m+street_length+1-4, mapI_n+street_length+4) = EMPTY_STREET;
88     % top, right
89     map(mapI_m+street_length+3, mapI_n+street_length+1-4) = EMPTY_STREET; %
90     left, top
91     map(mapI_m+street_length+4, mapI_n+street_length+1-4) = EMPTY_STREET; %
92     left, bottom
93     map(mapI_m+street_length+6+4, mapI_n+street_length+3) = EMPTY_STREET; %
94     bottom, left
95     map(mapI_m+street_length+6+4, mapI_n+street_length+4) = EMPTY_STREET; %
96     bottom, right
97     map(mapI_m+street_length+3, mapI_n+street_length+6+4) = EMPTY_STREET; %
98     right, top
99     map(mapI_m+street_length+4, mapI_n+street_length+6+4) = EMPTY_STREET; %
100    right, bottom
101 end
102 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
103 %write crossing into map
104 %check if intersection is a crossing with priority to the right
105 if ( config(a,b) == 1 )
106     %define index starting points for this crossroad
107     pI_m = (a - 1) * 6;
108     pI_n = (b - 1) * 6;
109     pIl_n = (b - 1) * 12; % index for light
110     pIt_m = (a - 1) * 4; % m-index for trace left
111     pIt_n = (b - 1) * 8; % n-index for trace left
112     %write crossroad into map
113     map(mapI_m+street_length+1:mapI_m+street_length+6, ...
114         mapI_n+street_length+1:mapI_n+street_length+6) = ...
115         street_crossroad(pI_m+1:pI_m+6, pI_n+1:pI_n+6);
116
117     %traffic lights
118     GREEN_LIGHT = 1.3;
119     RED_LIGHT = 1.6;
120     light(light==1) = GREEN_LIGHT;
121     light(light==0) = RED_LIGHT;
122
123     map(mapI_m+street_length-2, mapI_n+street_length+1) = light(a, pIl_n
124         +0*3+3); % top, inwards

```

```

114 map(mapI_m+street_length-2, mapI_n+street_length+4) = light(a, pI_l_n
    +0*3+2); % top, trace_left
115 map(mapI_m+street_length-1, mapI_n+street_length+6) = light(a, pI_l_n
    +0*3+1); % top, pedestrians
116
117 map(mapI_m+street_length+1, mapI_n+street_length-1) = light(a, pI_l_n
    +1*3+1); % left, pedestrians
118 map(mapI_m+street_length+3, mapI_n+street_length-2) = light(a, pI_l_n
    +1*3+2); % left, trace_left
119 map(mapI_m+street_length+6, mapI_n+street_length-2) = light(a, pI_l_n
    +1*3+3); % left, inwards
120
121 map(mapI_m+street_length+6+2, mapI_n+street_length+1) = light(a, pI_l_n
    +2*3+1); % bottom, pedestrians
122 map(mapI_m+street_length+6+3, mapI_n+street_length+3) = light(a, pI_l_n
    +2*3+2); % bottom, trace_left
123 map(mapI_m+street_length+6+3, mapI_n+street_length+6) = light(a, pI_l_n
    +2*3+3); % bottom, inwards
124
125 map(mapI_m+street_length+1, mapI_n+street_length+6+3) = light(a, pI_l_n
    +3*3+3); % right, inwards
126 map(mapI_m+street_length+4, mapI_n+street_length+6+3) = light(a, pI_l_n
    +3*3+2); % right, trace_left
127 map(mapI_m+street_length+6, mapI_n+street_length+6+2) = light(a, pI_l_n
    +3*3+1); % right, pedestrians
128
129 %trace left
130 trace_left_length = STREET_INTERSECTION+1;
131 for i = 1:trace_left_length
132     map(mapI_m+street_length+7+trace_left_length-i, mapI_n+street_length
        +4) = trace_left(pI_t_m+3, pI_t_n+i); % bottom, trace_left
133     map(mapI_m+street_length+3, mapI_n+street_length+7+trace_left_length-i)
        = trace_left(pI_t_m+4, pI_t_n+i); % right, trace_left
134     map(mapI_m+street_length-trace_left_length+i, mapI_n+street_length+3)
        = trace_left(pI_t_m+1, pI_t_n+i); % top, trace_left
135     map(mapI_m+street_length+4, mapI_n+street_length-trace_left_length+i)
        = trace_left(pI_t_m+2, pI_t_n+i); % left, trace_left
136 end
137
138 %write streets into map
139 for i = 1:street_length
140     map(mapI_m+i, mapI_n+street_length+2) = street_inwards(tI_m+1, tI_n+i)
        ; % top, inwards
141     map(mapI_m+street_length+5, mapI_n+i) = street_inwards(tI_m+2, tI_n+i)
        ; % left, inwards
142     map(mapI_m+2*street_length+7-i, mapI_n+street_length+5) =
        street_inwards(tI_m+3, tI_n+i); % bottom, inwards
143     map(mapI_m+street_length+2, mapI_n+2*street_length+7-i) =
        street_inwards(tI_m+4, tI_n+i); % right, inwards
144     map(mapI_m+street_length+1-i, mapI_n+street_length+5) =
        street_outwards(tI_m+1, tI_n+i); % top, outwards
145     map(mapI_m+street_length+2, mapI_n+street_length+1-i) =
        street_outwards(tI_m+2, tI_n+i); % left, outwards
146     map(mapI_m+street_length+6+i, mapI_n+street_length+2) =
        street_outwards(tI_m+3, tI_n+i); % bottom, outwards
147     map(mapI_m+street_length+5, mapI_n+street_length+6+i) =
        street_outwards(tI_m+4, tI_n+i); % right, outwards
148 end

```



```

149         end
150
151     end
152 end
153
154 % %illustrate traffic situation (now, not of next time step)
155 % fig1 = figure(1);
156 % imagesc(map);
157 % load('colormap2', 'mycmap')
158 % set(fig1, 'Colormap', mycmap)
159 % titlestring = sprintf('Density = %g', car_density);
160 % title(titlestring);
161 % drawnow;
162
163 end

```

References