RS-HL-14: Multi User Congestion Game

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Configuration of Congestion Game

Algorithm for C

I. Load the Dataset

```
clear;clc;
% Load the Satellite Contat Dataset
addpath('~/Desktop/Redstone_Project/RS_HL/RS_HL_10_TV_MDP_Functions')
load('/workspace/RS_Dataset/RS_HL_3_dataset.mat')
```

II. Destination Setting and Time Index Vector Setting

```
time_index_vector = 100:130;
start_time_index = 100:120;

number_of_agents = 100;
number_of_destinations = 5;
state_vector = 1:48;

start_state = state_vector(randi(numel(state_vector), 1, number_of_agents));
destination_values = randsample(state_vector,number_of_destinations);
destination_state = destination_values(randi(numel(destination_values), 1,
number_of_agents));
start_time = start_time_index(randi(numel(start_time_index), 1,
number_of_agents));
```

II.1 Run the MDP simulation for each destination

```
fprintf('Total Number of Destinations: %d\n', number_of_destinations);
```

```
Total Number of Destinations: 5
```

```
for destination_index = 1:number_of_destinations
    fprintf('--------------------------------------\n')
```

```
    fprintf('Running MDP %d / %d , Destination %d \n',
destination_index,number_of_destinations,destination_values(destination_index
));
    MDP.(['MDP', num2str(destination_values(destination_index))])
= runMDP(sat_to_sat_contact_3d_matrix,
time_index_vector,destination_values(destination_index));

end
```

```
--------------------------------------
Running MDP 1 / 5 , Destination 10
simulation set up complete!
Policy: 1 -> Value Iteration: 416
Policy: 2 -> Value Iteration: 14
Policy: 3 -> Value Iteration: 7
Policy: 4 -> Value Iteration: 5
Policy: 5 -> Value Iteration: 5
Policy: 6 -> Value Iteration: 8
Policy: 7 -> Value Iteration: 3
--------------------------------------
Running MDP 2 / 5 , Destination 3
simulation set up complete!
Policy: 1 -> Value Iteration: 411
Policy: 2 -> Value Iteration: 14
Policy: 3 -> Value Iteration: 8
Policy: 4 -> Value Iteration: 5
Policy: 5 -> Value Iteration: 5
Policy: 6 -> Value Iteration: 4
Policy: 7 -> Value Iteration: 8
Policy: 8 -> Value Iteration: 4
Policy: 9 -> Value Iteration: 1
--------------------------------------
Running MDP 3 / 5 , Destination 20
simulation set up complete!
Policy: 1 -> Value Iteration: 460
Policy: 2 -> Value Iteration: 14
Policy: 3 -> Value Iteration: 5
Policy: 4 -> Value Iteration: 5
Policy: 5 -> Value Iteration: 5
Policy: 6 -> Value Iteration: 11
Policy: 7 -> Value Iteration: 4
Policy: 8 -> Value Iteration: 5
Policy: 9 -> Value Iteration: 1
Policy: 10 -> Value Iteration: 1
Policy: 11 -> Value Iteration: 1
Policy: 12 -> Value Iteration: 1
Policy: 13 -> Value Iteration: 1
Policy: 14 -> Value Iteration: 1
Policy: 15 -> Value Iteration: 1
--------------------------------------
Running MDP 4 / 5 , Destination 22
simulation set up complete!
Policy: 1 -> Value Iteration: 430
Policy: 2 -> Value Iteration: 14
Policy: 3 -> Value Iteration: 8
Policy: 4 -> Value Iteration: 5
Policy: 5 -> Value Iteration: 7
Policy: 6 -> Value Iteration: 11
Policy: 7 -> Value Iteration: 4
Policy: 8 -> Value Iteration: 3
Policy: 9 -> Value Iteration: 1
Policy: 10 -> Value Iteration: 1
```

```
------------------------------------
Running MDP 5 / 5 , Destination 13
simulation set up complete!
Policy: 1 -> Value Iteration: 422
Policy: 2 -> Value Iteration: 14
Policy: 3 -> Value Iteration: 5
Policy: 4 -> Value Iteration: 5
Policy: 5 -> Value Iteration: 6
Policy: 6 -> Value Iteration: 9
Policy: 7 -> Value Iteration: 4
Policy: 8 -> Value Iteration: 9
Policy: 9 -> Value Iteration: 7
Policy: 10 -> Value Iteration: 1
Policy: 11 -> Value Iteration: 1
Policy: 12 -> Value Iteration: 1
```

```
    fprintf('--------------------------------------\n')
```

```
------------------------------------
```

III. Configure each Agent's Setting

```
agents_input = [start_time', start_state', destination_state'];
```

IV. Configure the simulation structure setting

```
% Level 1: Initialize simulation structure
sim = struct();

for time_index = time_index_vector
    sim.(['time' num2str(time_index)]) = {};
end

% Level 2/3: Initialize Agent (Level 2) with States and Destination (Level 3)

number_of_agents = length(agents_input(:,1));

for agent_index = 1:number_of_agents
   sim.(['time' num2str(agents_input(agent_index,1))]).(['agent'
num2str(agent_index)]).('state') = agents_input(agent_index,2);
   sim.(['time' num2str(agents_input(agent_index,1))]).(['agent'
num2str(agent_index)]).('destination') = agents_input(agent_index,3);
end
```

V. Configuration of Action Value Structure and Simulation Structure

```
% Initialize Action Value Structure
action_value_struct = struct();


for time_index = time_index_vector

    % If there's no active agent, continue to next time step
    if isempty(sim.(['time' num2str(time_index)]))
       continue;
    end


    % Parse the number of active agents
    number_of_active_agents = length(fieldnames(sim.(['time'
num2str(time_index)])));

    % Make the status matrix represents current and next
    % [current_state, next_state, destination]
    status_matrix = zeros(3, number_of_active_agents);

    agents_list = fieldnames(sim.(['time' num2str(time_index)]));

    % Definine Original Policy Distribution Matrix
    original_policy_matrix =
zeros(number_of_active_agents,length(state_vector));

    % Find the Next state from Current Agent-State
    for active_agent_index = 1:number_of_active_agents
        % Find the Current State and Destination of given agent
        current_state = sim.(['time' num2str(time_index)]).
(agents_list{active_agent_index}).('state');
        destination = sim.(['time' num2str(time_index)]).
(agents_list{active_agent_index}).('destination');

        % Get the Action values and corresponding next states from given
state in given MDP
        action_value_vector = MDP.(['MDP' num2str(destination)]).
(['time' num2str(time_index)]).(['state' num2str(current_state)]).
('action_value_vector');
        next_state_vector = MDP.(['MDP' num2str(destination)]).
(['time' num2str(time_index)]).(['state' num2str(current_state)]).
('next_state_vector');

        % Action Value Matrix Config: [Action index, Action Value Q, Next
State S']
        vector_length = length(action_value_vector);
        action_value_matrix = [(1:vector_length)',action_value_vector,
next_state_vector, action_value_vector];
        action_value_matrix = sortrows(action_value_matrix,2, 'descend');
```

```
        action_value_struct.(['time' num2str(time_index)]).
(agents_list{active_agent_index}).('action_value_matrix') =
action_value_matrix;

        % Find the Active Actoin Number from given Original MDP pi
distribution
        pi_dist = MDP.(['MDP' num2str(destination)]).(['time'
num2str(time_index)]).('policy_distribution');
        action_number = find(pi_dist(current_state,:) ~= 0);

        for action_number_index = 1:length(action_number)

original_policy_matrix(active_agent_index,action_number(action_number_index))
 = action_number(action_number_index);
        end

        % Get Activated Next States Vector (Which is from pi distribution)
        activated_next_states = action_number;
        action_value_struct.(['time' num2str(time_index)]).
(agents_list{active_agent_index}).('activated_next_states') =
activated_next_states;

        if length(action_number) > 1
        action_number = randsample(action_number,1);
        end

        next_state = MDP.(['MDP' num2str(destination)]).(['time'
num2str(time_index)]).(['state' num2str(current_state)]).(['action'
num2str(action_number)]).('success').('next_state');
        reward = MDP.(['MDP' num2str(destination)]).(['time'
num2str(time_index)]).(['state' num2str(current_state)]).(['action'
num2str(action_number)]).('success').('reward');
        state_value =  MDP.(['MDP' num2str(destination)]).(['time'
num2str(time_index)]).(['state' num2str(current_state)]).('state_value');
        action_value  = MDP.(['MDP' num2str(destination)]).
(['time' num2str(time_index)]).(['state' num2str(current_state)]).(['action'
num2str(action_number)]).('action_value');

        % Configure Proposed status matrix for the collision test
        status_matrix(1,active_agent_index) = current_state;
        status_matrix(2,active_agent_index) = next_state;
        status_matrix(3,active_agent_index) = destination;

        % Add State Value
        sim.(['time' num2str(time_index)]).(agents_list{active_agent_index}).
('state_value') = state_value;

        % Save the Original Reward and action value to prepare the update
        sim.(['time' num2str(time_index)]).(agents_list{active_agent_index}).
('original_action_number') = action_number;
```

```
        sim.(['time' num2str(time_index)]).(agents_list{active_agent_index}).
('original_action_value') = action_value;
        sim.(['time' num2str(time_index)]).(agents_list{active_agent_index}).
('original_reward') = reward;

        % Add the action number, reward, action value (may be changed)
        sim.(['time' num2str(time_index)]).(agents_list{active_agent_index}).
('action_number') = action_number;
        sim.(['time' num2str(time_index)]).(agents_list{active_agent_index}).
('action_value') = action_value;
        sim.(['time' num2str(time_index)]).(agents_list{active_agent_index}).
('reward') = reward;
    end
```

V.1 Policy Iteration By Updating Q values of potential Collision by given policy distribution

```
    updated_policy_matrix =
zeros(number_of_active_agents,length(state_vector));
    policy_iteration = 0;
    congestion_cost_factor = 10;

    while true
    % while isequal(original_policy_matrix,updated_policy_matrix) == false
    policy_iteration  = policy_iteration + 1;

    if policy_iteration > 1
        original_policy_matrix = updated_policy_matrix;
    end


    for active_agent_index = 1:number_of_active_agents

       action_value_matrix = action_value_struct.
(['time' num2str(time_index)]).(agents_list{active_agent_index}).
('action_value_matrix');
       action_value_matrix_original = action_value_matrix;

       number_of_actions = length(action_value_matrix(:,1));

       for test_agent_index = 1:number_of_active_agents
          if active_agent_index == test_agent_index
              continue;
          end
```

```
            index_starting_next_timestep = find(agents_input(:,1) ==
time_index+1);
            agents_input_extracted =
agents_input(index_starting_next_timestep,:);

            starting_state_list = agents_input_extracted(:,2)';

            test_activated_next_index =
original_policy_matrix(active_agent_index);
            text_activated_next_states =
test_activated_next_index(test_activated_next_index ~= 0);
            % test_activated_next_states
= action_value_struct.(['time' num2str(time_index)]).
(agents_list{test_agent_index}).('activated_next_states');
            test_activated_states = [text_activated_next_states,
starting_state_list];

            for action_index = 1:number_of_actions
                action_value_mat_next_state =
action_value_matrix(action_index,3);
                congestion_indicator = length(find(test_activated_states ==
action_value_mat_next_state));
                current_action_value = action_value_matrix(action_index,2);
                updated_action_value = current_action_value -
congestion_cost_factor * congestion_indicator;
                action_value_matrix(action_index,4) = updated_action_value;
            end
        end
        % if isequal(action_value_matrix(:,1),
action_value_matrix_updated(:,1)) == false
        %       fprintf('there was correctance \n')
        % end


        action_value_struct.(['time' num2str(time_index)]).
(agents_list{active_agent_index}).('action_value_matrix') =
action_value_matrix;

         % Policy Iteration Process -> Should Be Done

    end


    % Update The Action Number

    for active_agent_index = 1:number_of_active_agents
        % Find the Current State and Destination of given agent
        current_state = sim.(['time' num2str(time_index)]).
(agents_list{active_agent_index}).('state');
```

```
        destination = sim.(['time' num2str(time_index)]).
(agents_list{active_agent_index}).('destination');

        % if current_state == destination
        %     continue;
        % end

        action_value_matrix = action_value_struct.
(['time' num2str(time_index)]).(agents_list{active_agent_index}).
('action_value_matrix');
        updated_action_value_vector = max(action_value_matrix(:,4));
        updated_action_index = find(updated_action_value_vector ==
action_value_matrix(:,4));
        updated_action_policy = action_value_matrix(updated_action_index,1);

        for index = 1:length(updated_action_policy)
            updated_policy_matrix(active_agent_index,
updated_action_policy(index)) = updated_action_policy(index);
        end


        % Get Activated Next States Vector (Which is from pi distribution)
        activated_next_states_updated =
updated_policy_matrix(active_agent_index,:);
        activated_next_states_updated =
activated_next_states_updated(activated_next_states_updated ~= 0)';
        action_value_struct.(['time' num2str(time_index)]).
(agents_list{active_agent_index}).('activated_next_states') =
activated_next_states_updated';


        if length(updated_action_index) > 1
        updated_action_index = randsample(updated_action_index,1);
        end

        action_number = action_value_matrix(updated_action_index,1);
        action_value = action_value_matrix(updated_action_index,2);
        next_state = action_value_matrix(updated_action_index,3);
        reward =  MDP.(['MDP' num2str(destination)]).(['time'
num2str(time_index)]).(['state' num2str(current_state)]).(['action'
num2str(action_number)]).('success').('reward');

        % Modify Proposed status matrix for the collision test
        status_matrix(1,active_agent_index) = current_state;
        status_matrix(2,active_agent_index) = next_state;
        status_matrix(3,active_agent_index) = destination;

        % Modify the action number, reward, action value (may be changed)
        sim.(['time' num2str(time_index)]).(agents_list{active_agent_index}).
('action_number') = action_number;
```

```
        sim.(['time' num2str(time_index)]).(agents_list{active_agent_index}).
('action_value') = action_value;
        sim.(['time' num2str(time_index)]).(agents_list{active_agent_index}).
('reward') = reward;

        % original_action_number = sim.(['time' num2str(time_index)]).
(agents_list{active_agent_index}).('original_action_number');
        % Check the Update of the values
        % if isequal(action_number, original_action_number) == false
        %     fprintf('action_number changed from %d to %d
\n',original_action_number,action_number)
        %     time_index
        %     agents_list{active_agent_index}
        %     sim.(['time' num2str(time_index)]).
(agents_list{active_agent_index})
        % end

    end

        if isequal(original_policy_matrix,updated_policy_matrix) == true
        break;
        end
    end

    fprintf('Policy Iteration Completed at time %d by %d iterations
\n',time_index, policy_iteration)
```

V.1 Propagation With Randomness

```
    % Break when time index reaches the end time
    if time_index == max(time_index_vector)
       break;
    end

    % Actual Propagation of The State by Time

    for active_agent_index = 1:number_of_active_agents


        % Don't update the agent already arrived to destination
        if status_matrix(1,active_agent_index) ==
status_matrix(3,active_agent_index)
            continue;
        end

    % Generate Random Factor
```

```
    random_factor = rand(1,1);

    % Call the Current State, Destination, and Action Number of given agent
    current_state = sim.(['time' num2str(time_index)]).
(agents_list{active_agent_index}).('state');
    destination = sim.(['time' num2str(time_index)]).
(agents_list{active_agent_index}).('destination');
    action_number = sim.(['time' num2str(time_index)]).
(agents_list{active_agent_index}).('action_number');

    transmission_probability = MDP.(['MDP' num2str(destination)]).
(['time' num2str(time_index)]).(['state' num2str(current_state)]).(['action'
num2str(action_number)]).('success').('transition_probability');
        if random_factor > -1
        % if random_factor > 1 - transmission_probability
            % Update the time+1 for next state
            sim.(['time' num2str(time_index+1)]).
(agents_list{active_agent_index}).('state') =
status_matrix(2,active_agent_index);
            sim.(['time' num2str(time_index+1)]).
(agents_list{active_agent_index}).('destination') =
status_matrix(3,active_agent_index);
        else
            sim.(['time' num2str(time_index+1)]).
(agents_list{active_agent_index}).('state') = current_state;
            sim.(['time' num2str(time_index+1)]).
(agents_list{active_agent_index}).('destination') =
status_matrix(3,active_agent_index);
            % Since it is failure, we should replace reward as failure
penalty
            failure_reward = MDP.(['MDP' num2str(destination)]).
(['time' num2str(time_index)]).(['state' num2str(current_state)]).(['action'
num2str(action_number)]).('fail').('reward');
            sim.(['time' num2str(time_index)]).
(agents_list{active_agent_index}).('reward') = failure_reward;
        end
    end
end
```

```
Policy Iteration Completed at time 100 by 2 iterations
Policy Iteration Completed at time 101 by 1 iterations
Policy Iteration Completed at time 102 by 2 iterations
Policy Iteration Completed at time 103 by 2 iterations
Policy Iteration Completed at time 104 by 3 iterations
Policy Iteration Completed at time 105 by 2 iterations
Policy Iteration Completed at time 106 by 3 iterations
Policy Iteration Completed at time 107 by 3 iterations
Policy Iteration Completed at time 108 by 1 iterations
Policy Iteration Completed at time 109 by 2 iterations
Policy Iteration Completed at time 110 by 2 iterations
Policy Iteration Completed at time 111 by 1 iterations
Policy Iteration Completed at time 112 by 3 iterations
Policy Iteration Completed at time 113 by 2 iterations
```

```
Policy Iteration Completed at time 114 by 1 iterations
Policy Iteration Completed at time 115 by 3 iterations
Policy Iteration Completed at time 116 by 2 iterations
Policy Iteration Completed at time 117 by 1 iterations
Policy Iteration Completed at time 118 by 2 iterations
Policy Iteration Completed at time 119 by 2 iterations
Policy Iteration Completed at time 120 by 1 iterations
Policy Iteration Completed at time 121 by 3 iterations
Policy Iteration Completed at time 122 by 3 iterations
Policy Iteration Completed at time 123 by 1 iterations
Policy Iteration Completed at time 124 by 1 iterations
Policy Iteration Completed at time 125 by 1 iterations
Policy Iteration Completed at time 126 by 1 iterations
Policy Iteration Completed at time 127 by 1 iterations
Policy Iteration Completed at time 128 by 1 iterations
Policy Iteration Completed at time 129 by 1 iterations
Policy Iteration Completed at time 130 by 1 iterations
```

VI. result display

```
result_matrix = zeros(length(time_index_vector),number_of_agents);
reward_matrix =  zeros(length(time_index_vector),number_of_agents);
state_value_matrix = zeros(length(time_index_vector),number_of_agents);
action_value_matrix = zeros(length(time_index_vector),number_of_agents);
cumulative_reward_matrix = zeros(length(time_index_vector),number_of_agents);

for time_index = time_index_vector

    if isempty(sim.(['time' num2str(time_index)]))
     continue;
    end

    agents_list = fieldnames(sim.(['time' num2str(time_index)]));
    number_of_agents = length(agents_list);

    for agent_index = 1:number_of_agents
        agent_name = cell2mat(agents_list(agent_index));
        agent_no = regexp(agent_name, '\d+','match');
        agent_number = str2double(agent_no{1});

        result_matrix(time_index - min(time_index_vector) + 1,agent_number)
= sim.(['time' num2str(time_index)]).(agent_name).('state');
        reward_matrix(time_index - min(time_index_vector) + 1,agent_number)
=  sim.(['time' num2str(time_index)]).(agent_name).('reward');
        state_value_matrix(time_index - min(time_index_vector)
+ 1,agent_number) = sim.(['time' num2str(time_index)]).(agent_name).
('state_value');
```

```
        action_value_matrix(time_index - min(time_index_vector)
+ 1,agent_number) = sim.(['time' num2str(time_index)]).(agent_name).
('action_value');
        cumulative_reward_matrix(time_index - min(time_index_vector) +
1,agent_number) = sum(reward_matrix(1:time_index - min(time_index_vector) +
1,agent_number));

    end

end

result = [time_index_vector' , result_matrix]
```

```
result = 31×101
   100     0     0     0     0     0     0     0     0     0     0     0     0 ···
   101     0    32     9     0     0     0     0     0     0     0     0     0
   102     0    11     8     0     0     0     0     0     0    45    14     0
   103    13    12     7     0     0     0     0    25     0    21    15     0
   104    14    13     6     0     0     0     0    23     0    22    16     0
   105    15     0     5     0     0     0     0    22     0     0    17     0
   106    16     0     4     0     0     0     0     0     0     0    18     0
   107    17     0     3     0     0    34     0     0     0     0    19     0
   108    18     0     0     3     0     8     0     0     0     0    20     0
   109    19     0     0     4     0     7     0     0     0     0     0     0
     ⋮
```

```
reward = [time_index_vector', reward_matrix]
```

```
reward = 31×101
   100     0     0     0     0     0     0     0     0     0     0     0     0 ···
   101     0   -15    -1     0     0     0     0     0     0     0     0     0
   102     0    -1    -1     0     0     0     0     0     0   -15    -1     0
   103    -1   100    -1     0     0     0     0   -15     0   100    -1     0
   104    -1     0    -1     0     0     0     0   100     0     0    -1     0
   105    -1     0    -1     0     0     0     0     0     0     0    -1     0
   106    -1     0   100     0     0     0     0     0     0     0    -1     0
   107    -1     0     0     0     0   -15     0     0     0     0   100     0
   108    -1     0     0    -1     0    -1     0     0     0     0     0     0
   109   100     0     0    -1     0    -1     0     0     0     0     0     0
     ⋮
```

```
cumulative_reward = [time_index_vector', cumulative_reward_matrix]
```

```
cumulative_reward = 31×101
   100     0     0     0     0     0     0     0     0     0     0     0     0 ···
   101     0   -15    -1     0     0     0     0     0     0     0     0     0
   102     0   -16    -2     0     0     0     0     0     0   -15    -1     0
   103    -1    84    -3     0     0     0     0   -15     0    85    -2     0
   104    -2    84    -4     0     0     0     0    85     0    85    -3     0
   105    -3     0    -5     0     0     0     0    85     0     0    -4     0
   106    -4     0    95     0     0     0     0     0     0     0    -5     0
   107    -5     0    95     0     0   -15     0     0     0     0    95     0
   108    -6     0     0    -1     0   -16     0     0     0     0    95     0
   109    94     0     0    -2     0   -17     0     0     0     0     0     0
     ⋮
```

```
state_value = [time_index_vector', state_value_matrix]
```

```
state_value = 31×101
  100.0000         0         0         0         0         0         0         0···
  101.0000         0   61.5000   50.0000         0         0         0         0
  102.0000         0   84.0000   58.5000         0         0         0         0
  103.0000   41.5000   92.5000   67.0000         0         0         0         0
  104.0000   50.0000         0   75.5000         0         0         0         0
  105.0000   58.5000         0   84.0000         0         0         0         0
  106.0000   67.0000         0   92.5000         0         0         0         0
  107.0000   75.5000         0         0         0         0   36.0000         0
  108.0000   84.0000         0         0   41.5000         0   58.5000         0
  109.0000   92.5000         0         0   50.0000         0   67.0000         0
      ⋮
```

```
action_value = [time_index_vector', action_value_matrix]
```

```
action_value = 31×101
  100.0000         0         0         0         0         0         0         0···
  101.0000         0   61.5000   50.0000         0         0         0         0
  102.0000         0   84.0000   58.5000         0         0         0         0
  103.0000   41.5000   92.5000   67.0000         0         0         0         0
  104.0000   50.0000         0   75.5000         0         0         0         0
  105.0000   58.5000         0   84.0000         0         0         0         0
  106.0000   67.0000         0   92.5000         0         0         0         0
  107.0000   75.5000         0         0         0         0   36.0000         0
  108.0000   84.0000         0         0   41.5000         0   58.5000         0
  109.0000   92.5000         0         0   50.0000         0   67.0000         0
      ⋮
```

VI.1 Chack Congestion Factor in Result Matrix

```
congestion_factor_vector = zeros(length(result(:,1)),1);
for result_index = 1:length(result(:,1))
 states_vector = result(result_index,2:end);
 active_agent_vector = states_vector(states_vector ~= 0);
 unique_active_agent_vector = unique(active_agent_vector);
 congestion_factor_vector(result_index) = length(active_agent_vector) -
length(unique_active_agent_vector);
end

congestion_factor_vector'
```

```
ans = 1×31
     1     1     4     6     7     7     7     6    10     8     7     5     4···
```

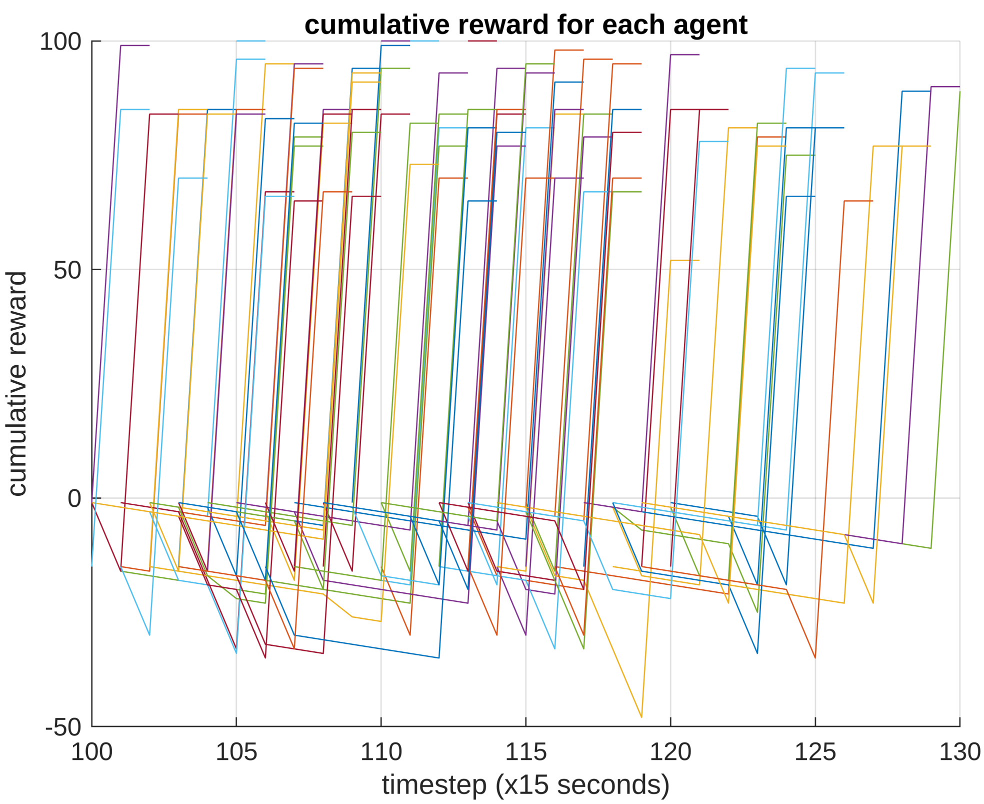
```
congestion_factor_sum = sum(congestion_factor_vector)
```

```
congestion_factor_sum = 123
```

VII. Result Graph

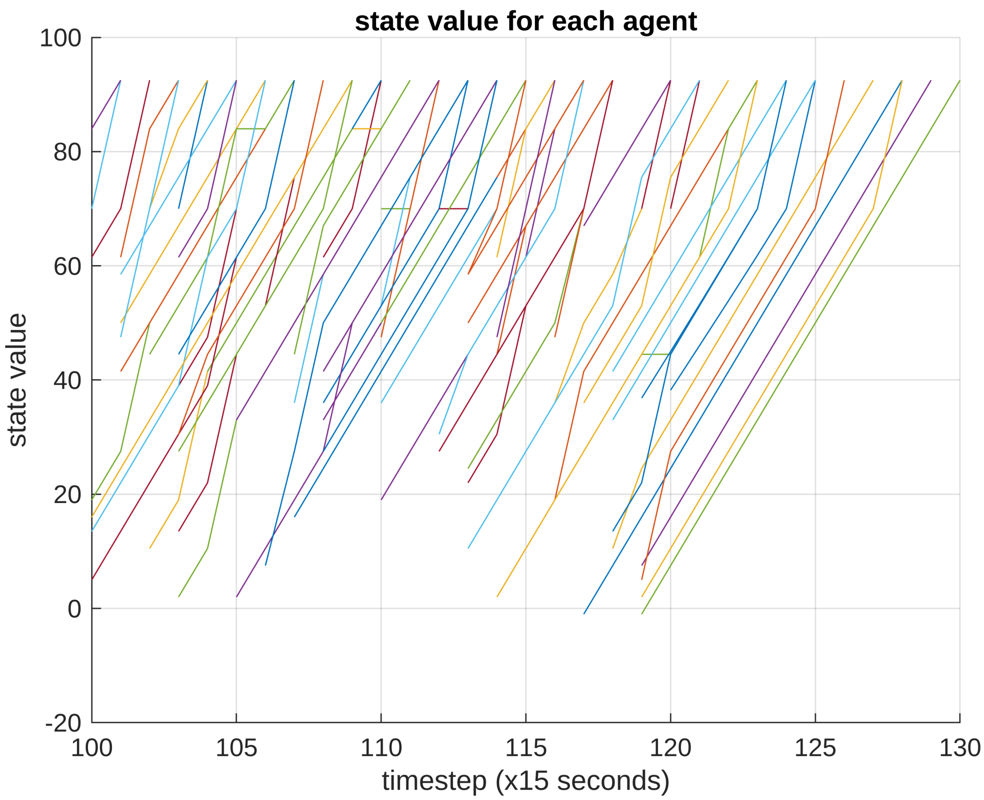
```
number_of_agents = length(agents_input(:,1));
```

```
figure;
hold on
for agent_index = 1:number_of_agents

    cumulative_reward_each_agent = [time_index_vector',
cumulative_reward_matrix(:,agent_index)];
    cumulative_reward_each_agent =
cumulative_reward_each_agent(cumulative_reward_each_agent(:,2) ~= 0, :);

   plot(cumulative_reward_each_agent(:,1),cumulative_reward_each_agent(:,2))

end
hold off
grid on
title('cumulative reward for each agent')
xlabel('timestep (x15 seconds)')
ylabel('cumulative reward')
```



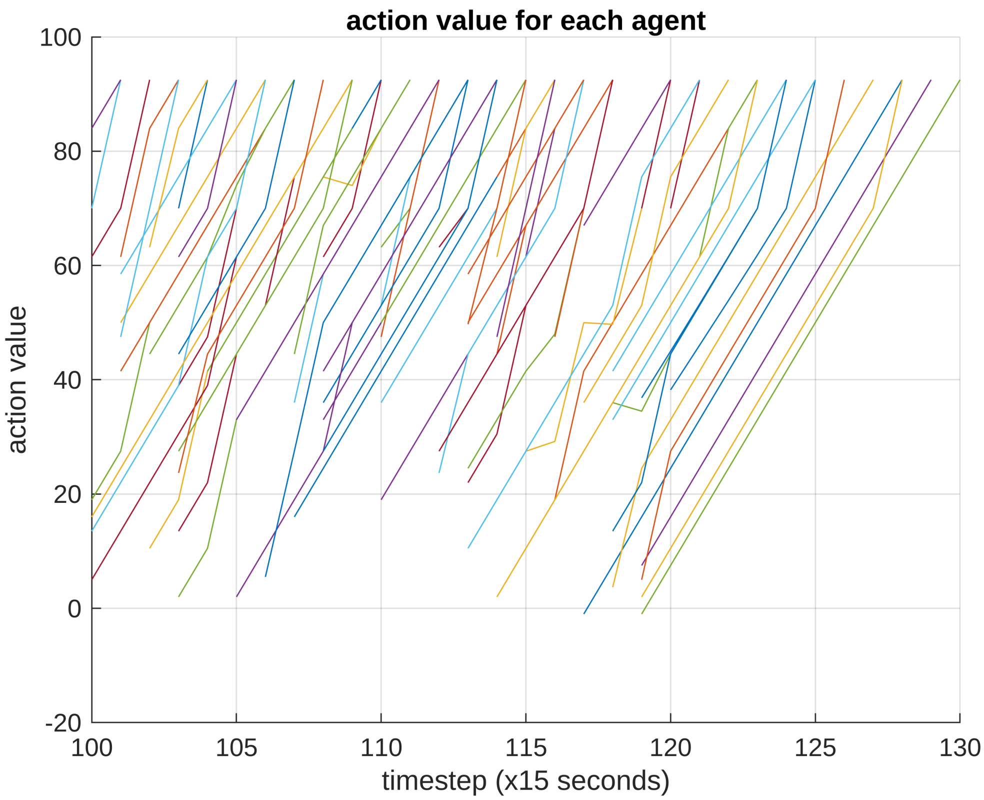

```
figure;
hold on
for agent_index = 1:number_of_agents

    state_value_each_agent = [time_index_vector',
state_value_matrix(:,agent_index)];
```

```
    state_value_each_agent =
state_value_each_agent(state_value_each_agent(:,2) ~= 0, :);

    plot(state_value_each_agent(:,1),state_value_each_agent(:,2))
end
hold off
grid on
title('state value for each agent')
xlabel('timestep (x15 seconds)')
ylabel('state value')
```




```
figure;
hold on
for agent_index = 1:number_of_agents

    action_value_each_agent = [time_index_vector',
action_value_matrix(:,agent_index)];
    action_value_each_agent =
action_value_each_agent(action_value_each_agent(:,2) ~= 0, :);
    plot(action_value_each_agent(:,1),action_value_each_agent(:,2))
end
hold off
grid on
title('action value for each agent')
xlabel('timestep (x15 seconds)')
```

```
ylabel('action value')
```




```
figure;
hold on
for agent_index = 1:number_of_agents

    state_value_each_agent = [time_index_vector',
state_value_matrix(:,agent_index)];
    state_value_each_agent =
state_value_each_agent(state_value_each_agent(:,2) ~= 0, :);


plot(state_value_each_agent(:,1),state_value_each_agent(:,2),'b','LineWidth',
2)
end


for agent_index = 1:number_of_agents

    action_value_each_agent = [time_index_vector',
action_value_matrix(:,agent_index)];
    action_value_each_agent =
action_value_each_agent(action_value_each_agent(:,2) ~= 0, :);
```

```
plot(action_value_each_agent(:,1),action_value_each_agent(:,2),'r','LineWidth
',1)
end
hold off
grid on
title('State(blue) and Action(red) Value Combined')
xlabel('timestep (x15 seconds)')
ylabel('state/action value')
```