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 = 4;
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: 4
```

```
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 / 4 , Destination 35
simulation set up complete!
Policy: 1 -> Value Iteration: 418
Policy: 2 -> Value Iteration: 14
Policy: 3 -> Value Iteration: 7
Policy: 4 -> Value Iteration: 5
Policy: 5 -> Value Iteration: 6
Policy: 6 -> Value Iteration: 11
Policy: 7 -> Value Iteration: 5
Policy: 8 -> Value Iteration: 1
-------------------------------------
Running MDP 2 / 4 , Destination 36
simulation set up complete!
Policy: 1 -> Value Iteration: 417
Policy: 2 -> Value Iteration: 13
Policy: 3 -> Value Iteration: 5
Policy: 4 -> Value Iteration: 5
Policy: 5 -> Value Iteration: 5
Policy: 6 -> Value Iteration: 6
Policy: 7 -> Value Iteration: 11
Policy: 8 -> Value Iteration: 1
Policy: 9 -> Value Iteration: 1
Policy: 10 -> Value Iteration: 1
-------------------------------------
Running MDP 3 / 4 , Destination 26
simulation set up complete!
Policy: 1 -> Value Iteration: 460
Policy: 2 -> Value Iteration: 14
Policy: 3 -> Value Iteration: 5
Policy: 4 -> Value Iteration: 6
Policy: 5 -> Value Iteration: 9
Policy: 6 -> Value Iteration: 8
Policy: 7 -> Value Iteration: 3
Policy: 8 -> Value Iteration: 3
Policy: 9 -> Value Iteration: 1
Policy: 10 -> Value Iteration: 1
-------------------------------------
Running MDP 4 / 4 , Destination 42
simulation set up complete!
Policy: 1 -> Value Iteration: 440
Policy: 2 -> Value Iteration: 14
Policy: 3 -> Value Iteration: 6
Policy: 4 -> Value Iteration: 5
Policy: 5 -> Value Iteration: 5
Policy: 6 -> Value Iteration: 7
Policy: 7 -> Value Iteration: 10
Policy: 8 -> Value Iteration: 9
Policy: 9 -> 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 = 1;
    factor = 30;


    while isequal(original_policy_matrix,updated_policy_matrix) == false

    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');
       original_action_value_matrix = 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_states = action_value_struct.
(['time' num2str(time_index)]).(agents_list{test_agent_index}).
('activated_next_states');
          test_activated_states = [test_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 - 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_matrix = sortrows(action_value_matrix,4, 'descend');
        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 = action_value_matrix(1,4);
        updated_action_policy = find(updated_action_value_vector ==
action_value_matrix(:,4));

        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_policy) > 1
        updated_action_policy = randsample(updated_action_policy,1);
        end

        action_number = action_value_matrix(updated_action_policy,1);
        action_value = action_value_matrix(updated_action_policy,2);
        next_state = action_value_matrix(updated_action_policy,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

    policy_iteration  = policy_iteration + 1;
```

```
    end
```

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
```

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     4     0     0 ···
   101     0     0     0    27     0     0    44     0     0     5     0     0
   102     0     0     0    28     0     0    45     0     0     6     0     0
   103     0     0     0     6     0     0    24     0     0    32     0     0
   104     8     0     0    32     0    14    26    17     0    33     0     0
   105     9     0     0    33     0    35     0    16     0    34     0     0
   106    10     0     0    34     0    36     0    37     0    35    22     0
   107    11     0     0    35     0     0     0    36     0    36    48     0
   108    36     0     0     0     0     0     0     0     0     0    25     0
   109    37     0     0     0     0     0     0     0     0     0    26     0
     ⋮
```

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

```
reward = 31×101
   100     0     0     0     0     0     0     0     0     0    -1     0     0 ···
   101     0     0     0    -1     0     0    -1     0     0    -1     0     0
   102     0     0     0   -15     0     0   -15     0     0   -15     0     0
   103     0     0     0   -15     0     0    75     0     0    -1     0     0
   104    -1     0     0    -1     0   -15     0    -1     0    -1     0     0
   105    -1     0     0    -1     0    75     0   -15     0    -1     0     0
   106    -1     0     0    75     0     0     0    75     0    75   -15     0
   107   -15     0     0     0     0     0     0     0     0     0    -1     0
   108    -1     0     0     0     0     0     0     0     0     0    75     0
   109    -1     0     0     0     0     0     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    -1     0     0 ···
   101     0     0     0    -1     0     0    -1     0     0    -2     0     0
   102     0     0     0   -16     0     0   -16     0     0   -17     0     0
   103     0     0     0   -31     0     0    59     0     0   -18     0     0
   104    -1     0     0   -32     0   -15    59    -1     0   -19     0     0
   105    -2     0     0   -33     0    60     0   -16     0   -20     0     0
   106    -3     0     0    42     0    60     0    59     0    55   -15     0
   107   -18     0     0    42     0     0     0    59     0    55   -16     0
   108   -19     0     0     0     0     0     0     0     0     0    59     0
   109   -20     0     0     0     0     0     0     0     0     0    59     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         0         0    8.0000         0         0   36.5000
  102.0000         0         0         0   16.5000         0         0   45.0000
  103.0000         0         0         0   28.0000         0         0   67.5000
  104.0000  -14.5000         0         0   50.5000         0   45.0000         0
  105.0000   -6.0000         0         0   59.0000         0   67.5000         0
  106.0000    2.5000         0         0   67.5000         0         0         0
  107.0000   11.0000         0         0         0         0         0         0
  108.0000   25.0000         0         0         0         0         0         0
  109.0000   33.5000         0         0         0         0         0         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         0         0    8.0000         0         0   36.5000
  102.0000         0         0         0    7.7000         0         0   45.0000
  103.0000         0         0         0   28.0000         0         0   67.5000
  104.0000  -14.5000         0         0   50.5000         0   45.0000         0
  105.0000   -6.0000         0         0   59.0000         0   67.5000         0
  106.0000    2.5000         0         0   67.5000         0         0         0
  107.0000    4.2000         0         0         0         0         0         0
  108.0000   25.0000         0         0         0         0         0         0
  109.0000   33.5000         0         0         0         0         0         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     0     0     1     2     3     6     6     7    11    11     8     7 ···
```

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

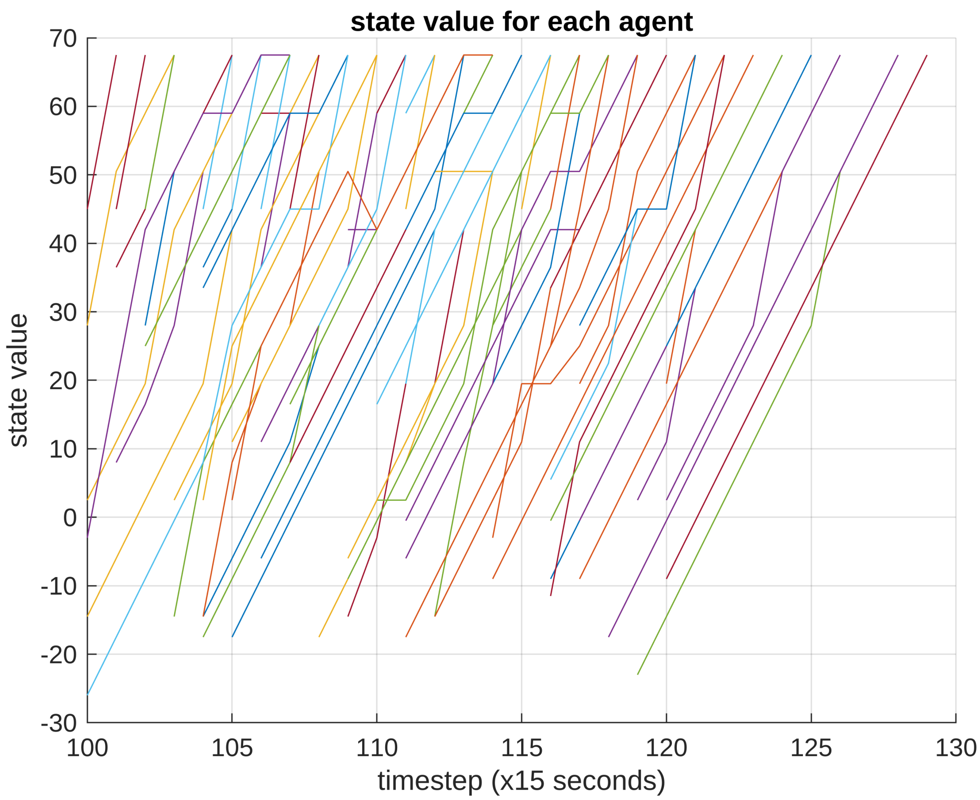
```
congestion_factor_sum = 157
```

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')
```

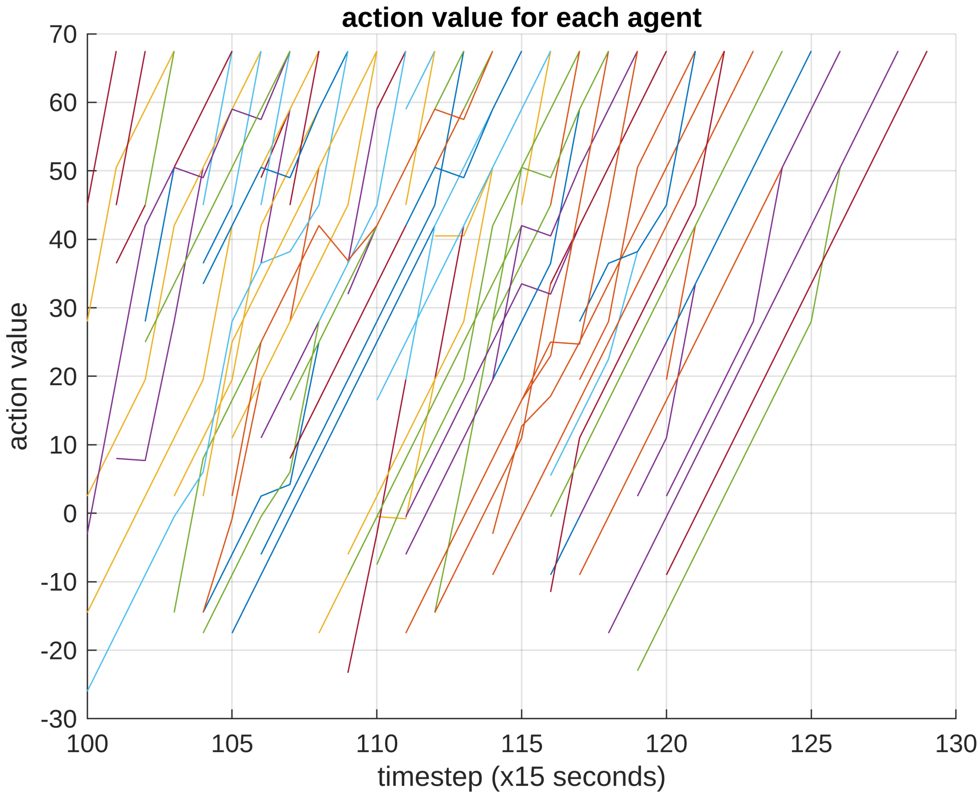

```
figure;
hold on
```

```
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')
```