# RS-HL-12: Multi User Code


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## 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;
%
% destination_1 = 10;
% destination_2 = 12;
% destination_3 = 18;
% destination_4 = 27;
% destination_5 = 40;


number_of_agents = 18;
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

```

number_of_destination = length(destination_values);
```

```
for destination_index = 1:number_of_destination

    MDP.(['MDP', num2str(destination_values(destination_index))])
= runMDP(sat_to_sat_contact_3d_matrix,
time_index_vector,destination_values(destination_index));

end

% MDP.(['MDP', num2str(18)]) = runMDP(sat_to_sat_contact_3d_matrix,
time_index_vector,18);
% MDP.(['MDP', num2str(28)]) = runMDP(sat_to_sat_contact_3d_matrix,
time_index_vector,28);
% MDP.(['MDP', num2str(42)]) = runMDP(sat_to_sat_contact_3d_matrix,
time_index_vector,42);
```

### III. Configure each Agent's Setting

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

% a_start = 31;
% a_destination = 18;
% a_time = 100;
%
%
% b_start = 31;
% b_destination= 28;
% b_time = 100;
%
% c_start = 31;
% c_destination = 42;
% c_time = 100;
%
% d_start = 31;
% d_destination = 18;
% d_time = 100;
%
% e_start = 31;
% e_destination = 18;
% e_time = 118;
%
%
% f_start = 14;
% f_destination = 28;
% f_time = 115;
%
```

```
% g_start = 10;
% g_destination = 42;
% g_time = 110;
%
% agents_input = [a_time, a_start, a_destination;
%                 b_time, b_start, b_destination;
%                 c_time, c_start, c_destination;
%                 d_time, d_start, d_destination;
%                 e_time, e_start, e_destination;
%                 f_time, f_start, f_destination;
%                 g_time, g_start, g_destination];
%
```

### 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. Propagation of agents' state

```
collision_flag = false;

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)]));

    % 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');

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

        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


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

    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

        % 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);
    end


    % Avoid Collision Avoidance Algorithm


    % If next state Agent info is empty, continue
    if isempty(sim.(['time' num2str(time_index+1)]))
        continue;
    end

    % Parse the number of next state active agents
```

```
    next_state_number_of_active_agents = length(fieldnames(sim.(['time'
num2str(time_index+1)])));
    next_state_status_matrix = zeros(1, next_state_number_of_active_agents);
    next_state_agents_list = fieldnames(sim.(['time'
num2str(time_index+1)]));

    for next_state_agent_index = 1:next_state_number_of_active_agents
        next_state_status_matrix(next_state_agent_index)
= sim.(['time' num2str(time_index+1)]).
(next_state_agents_list{next_state_agent_index}).('state');
    end

    unique_elements = unique(next_state_status_matrix);

    % If there is no collision -> contintue
    if length(next_state_status_matrix) == length(unique_elements)
        continue;
    end
```

### VI. If there exists Collision -> Activate Collision Avoidance Algorithm

```
    fprintf('collision occured at time index %d\n', time_index);
    % If there exist collision -> Start the infinite loop until the
    % problem resolved
    collision_flag = true;


    while collision_flag == true
     % Collect Action value vector of each agent's state

     action_value_struct = struct();
     vector_length_information = zeros(number_of_active_agents,1);

     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 value Matrix from given state in given MDP
        action_value_vector = MDP.(['MDP' num2str(destination)]).
(['time' num2str(time_index)]).(['state' num2str(current_state)]).
('action_value_vector');
        vector_length = length(action_value_vector);
        action_value_matrix = [(1:vector_length)',action_value_vector];
        action_value_matrix = sortrows(action_value_matrix,2, 'descend');
```

```
        if vector_length > 4
            action_value_matrix = action_value_matrix(1:4,:);
        end


        action_value_struct.(agents_list{active_agent_index}).
('action_value_matrix') = action_value_matrix;
        vector_length_information(active_agent_index) =
length(action_value_matrix(:,1));
     end


     % Generate Cases For Each Action Value
     combination_matrix = [];

     for active_agent_index = 1:number_of_active_agents-1
        new_matrix = [];
        if active_agent_index == 1
           pre_matrix = (1:vector_length_information(active_agent_index))';
        else
           pre_matrix = combination_matrix;
        end

        length_of_pre_matrix = length(pre_matrix(:,1));

        for next_agent_index =
1:vector_length_information(active_agent_index+1)

        adding_vector = ones(length_of_pre_matrix,1)*next_agent_index;
        new_matrix_segment = [pre_matrix,adding_vector];
        new_matrix = [new_matrix;new_matrix_segment];

        end
        combination_matrix = new_matrix;
     end


     if number_of_active_agents == 1
        combination_matrix =  (1:vector_length_information(1))';
     end

     action_number_matrix =
zeros(length(combination_matrix(:,1)),number_of_active_agents);
     action_value_matrix =
zeros(length(combination_matrix(:,1)),number_of_active_agents);
     action_value_sum_vector = zeros(length(combination_matrix(:,1)),1);
     next_state_matrix =
zeros(length(combination_matrix(:,1)),number_of_active_agents);
```

```
    for case_index = 1:length(combination_matrix(:,1))
        for active_agent_index = 1:number_of_active_agents
            action_index =
combination_matrix(case_index,active_agent_index);

            action_value_info =  action_value_struct.
(agents_list{active_agent_index}).('action_value_matrix');

            action_number = action_value_info(action_index,1);
            action_value = action_value_info(action_index,2);

            action_number_matrix(case_index,active_agent_index) =
action_number;
            action_value_matrix(case_index,active_agent_index) =
action_value;


            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');


            next_state_info =  MDP.(['MDP' num2str(destination)]).
(['time' num2str(time_index)]).(['state' num2str(current_state)]).(['action'
num2str(action_number)]).('success').('next_state');
            next_state_matrix(case_index,active_agent_index) =
next_state_info;

        end
        action_value_sum_vector(case_index) =
sum(action_value_matrix(case_index,:));
    end

    case_evaluation_matrix =
[next_state_matrix,action_number_matrix,action_value_sum_vector];
    case_evaluation_matrix =
sortrows(case_evaluation_matrix,length(case_evaluation_matrix(1,:)),
'descend');

    for  case_index = 1:length(combination_matrix(:,1))

       next_state =
case_evaluation_matrix(case_index,1:number_of_active_agents);
       % Modify Status Matrix for corresponding next state vector
       status_matrix(2,:) = next_state;
```

```
        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

            % Update states the time+1 for next state
            sim.(['time' num2str(time_index+1)]).
(agents_list{active_agent_index}).('state') =
status_matrix(2,active_agent_index);
        end

        % Parse the number of next state active agents
        next_state_number_of_active_agents = length(fieldnames(sim.(['time'
num2str(time_index+1)])));
        next_state_status_matrix = zeros(1,
next_state_number_of_active_agents);

        for next_state_agent_index = 1:next_state_number_of_active_agents
            next_state_status_matrix(next_state_agent_index)
= sim.(['time' num2str(time_index+1)]).
(next_state_agents_list{next_state_agent_index}).('state');
        end

        unique_elements = unique(next_state_status_matrix);

        % If there is no collision -> contintue
        if length(next_state_status_matrix) == length(unique_elements)
            selected_action_number_vector =
case_evaluation_matrix(case_index,number_of_active_agents+1:2*number_of_activ
e_agents);


           for active_agent_index = 1:number_of_active_agents

            action_number =
selected_action_number_vector(active_agent_index);
            % Parse the updated reward, state value and action value
            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');
            reward = MDP.(['MDP' num2str(destination)]).(['time'
num2str(time_index)]).(['state' num2str(current_state)]).(['action'
num2str(action_number)]).('success').('reward');
```

```
            % Modify the reward, state value and action value
            sim.(['time' num2str(time_index)]).
(agents_list{active_agent_index}).('reward') = reward;
            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;

           end


           fprintf('collision resolved at time index %d  at case index %d
\n', time_index, case_index);
           collision_flag = false;
           break;
        end

     end


     if collision_flag == true
         fprintf('we could not resolve the collision at time index %d\n',
time_index);
            break;
     end

    end

    if collision_flag == true

    fprintf('Simulation Terminated with fail');
    break;
    end
end

if collision_flag == false
fprintf('Simulation Terminated with Success')
end
```

### VI. result display

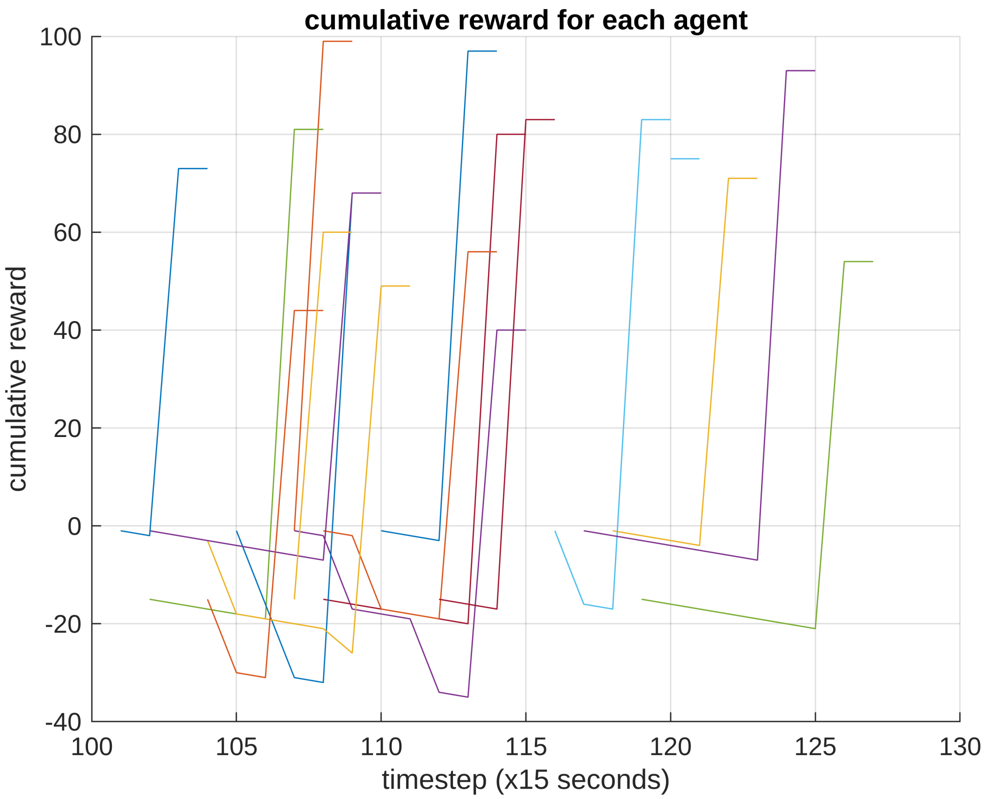
```
result_matrix = zeros(length(time_index_vector),number_of_agents);
reward_matrix =  zeros(length(time_index_vector),number_of_agents);
state_value_matrix = zeros(length(time_index_vector),number_of_agents);
action_value_matrix = zeros(length(time_index_vector),number_of_agents);
cumulative_reward_matrix = 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]
reward = [time_index_vector', reward_matrix]
cumulative_reward = [time_index_vector', cumulative_reward_matrix]
state_value = [time_index_vector', state_value_matrix]
action_value = [time_index_vector', action_value_matrix]
```

### VII. Result Graph

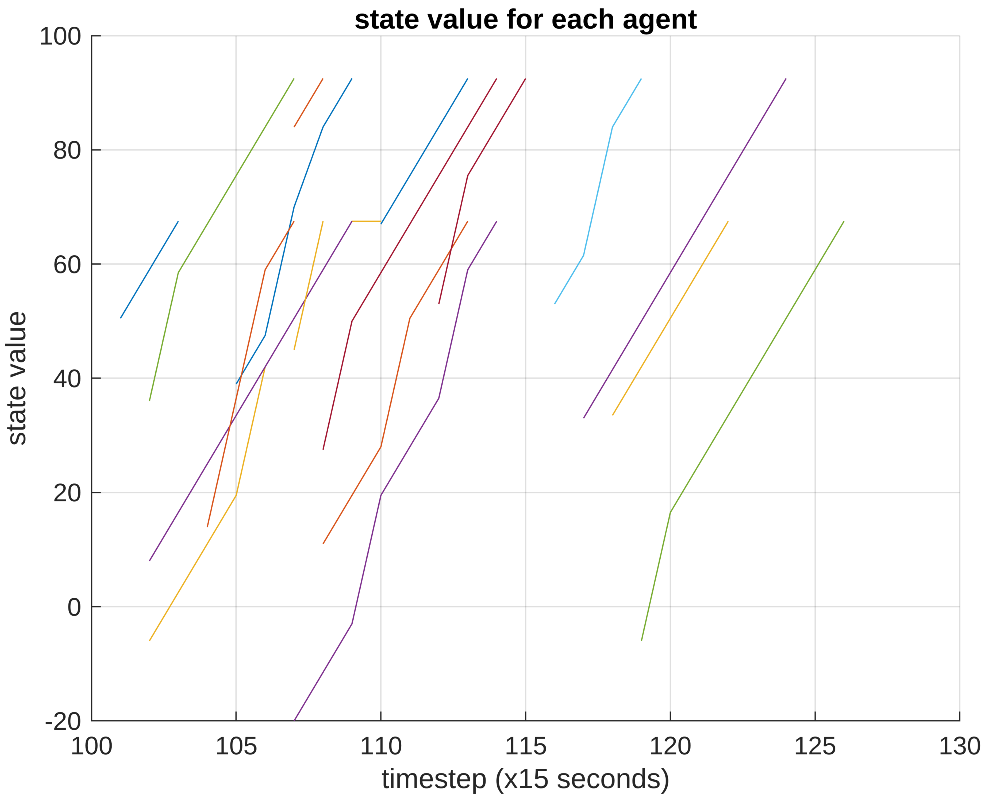
```
number_of_agents = length(agents_input(:,1));

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')
```

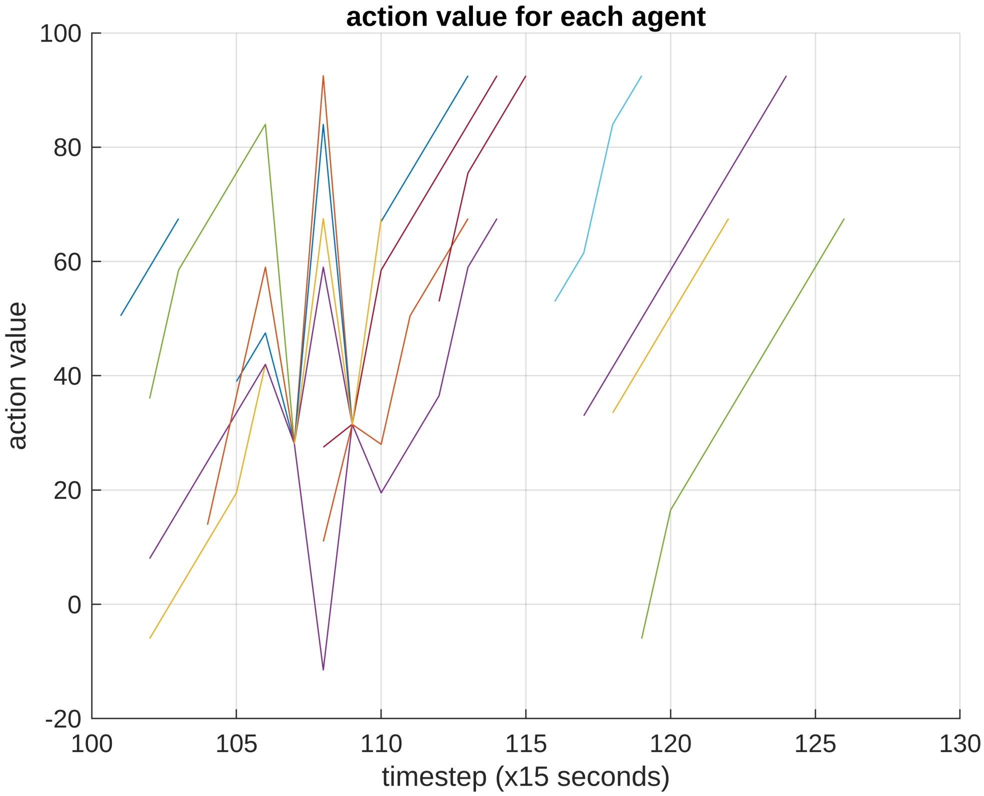



```

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')
```