RS-HL-12: Multi User Code

Hongseok Kim

UT Austin Oden Institute

07/20/24

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 = 25;
% 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

```
%
```

```
% 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
%     % propblem 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)
%
%            for active_agent_index = 1:number_of_active_agents
%
%             action_number =
action_number_matrix(case_index,active_agent_index);
%             action_value = action_value_matrix(case_index,
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');
%             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]
```

```
result = 31×26
   100     0     0     0     0     0     0     0     0    25     0     0     0 ···
   101     0     0     0     0    29     0     0     0    26     0     0     0
   102     0     0     0     0    28     0    37     0    27     0     0     0
   103     6     0     0     0    27     0    16     0    28     0     0     0
   104    28     0     0     0     0     0    17     0    29     0     0     0
   105    29     0     0     0     0     0    18     0     0     0     0     0
   106     0     0     0     0     0     0    19     0     0     0     0     0
   107     0     0     0     0     0     0    20     0     0     0     0     0
   108     0     0     0     0     0     0    21     0     0     0     0     0
   109     0     0     0     0     0    11    22     0     0     0     0     0
     ⋮
     ⋮
```

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

```
reward = 31×26
   100     0     0     0     0     0     0     0     0    -1     0     0     0 ···
   101     0     0     0     0    -1     0     0     0    -1     0     0     0
   102     0     0     0     0   100     0   -15     0    -1     0     0     0
   103   -15     0     0     0     0     0    -1     0   100     0     0     0
   104   100     0     0     0     0     0    -1     0     0     0     0     0
   105     0     0     0     0     0     0    -1     0     0     0     0     0
```

```
   106     0     0     0     0     0     0    -1     0     0     0     0     0
   107     0     0     0     0     0     0    -1     0     0     0     0     0
   108     0     0     0     0     0     0    -1     0     0     0     0     0
   109     0     0     0     0     0    -1    -1     0     0     0     0     0
     ⋮
     ⋮
```

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

```
cumulative_reward = 31×26
   100     0     0     0     0     0     0     0     0    -1     0     0     0 ···
   101     0     0     0     0    -1     0     0     0    -2     0     0     0
   102     0     0     0     0    99     0   -15     0    -3     0     0     0
   103   -15     0     0     0    99     0   -16     0    97     0     0     0
   104    85     0     0     0     0     0   -17     0    97     0     0     0
   105    85     0     0     0     0     0   -18     0     0     0     0     0
   106     0     0     0     0     0     0   -19     0     0     0     0     0
   107     0     0     0     0     0     0   -20     0     0     0     0     0
   108     0     0     0     0     0     0   -21     0     0     0     0     0
   109     0     0     0     0     0    -1   -22     0     0     0     0     0
     ⋮
     ⋮
```

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

```
state_value = 31×26
  100.0000         0         0         0         0         0         0         0 ···
  101.0000         0         0         0         0   84.0000         0         0
  102.0000         0         0         0         0   92.5000         0   19.0000
  103.0000   70.0000         0         0         0         0         0   41.5000
  104.0000   92.5000         0         0         0         0         0   50.0000
  105.0000         0         0         0         0         0         0   58.5000
  106.0000         0         0         0         0         0         0   67.0000
  107.0000         0         0         0         0         0         0   75.5000
  108.0000         0         0         0         0         0         0   84.0000
  109.0000         0         0         0         0         0   50.0000   92.5000
     ⋮
     ⋮
```

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

```
action_value = 31×26
  100.0000         0         0         0         0         0         0         0 ···
  101.0000         0         0         0         0   84.0000         0         0
  102.0000         0         0         0         0   92.5000         0   19.0000
  103.0000   70.0000         0         0         0         0         0   41.5000
  104.0000   92.5000         0         0         0         0         0   50.0000
  105.0000         0         0         0         0         0         0   58.5000
  106.0000         0         0         0         0         0         0   67.0000
  107.0000         0         0         0         0         0         0   75.5000
  108.0000         0         0         0         0         0         0   84.0000
  109.0000         0         0         0         0         0   36.4000   92.5000
     ⋮
     ⋮
```

VII. Result Graph

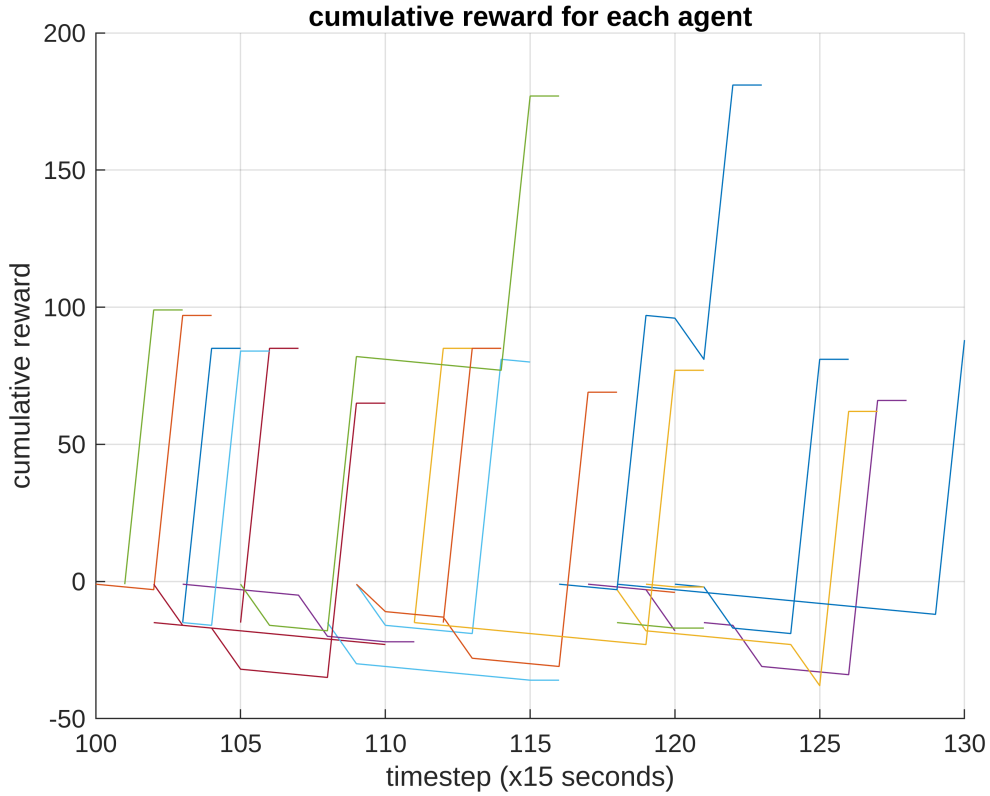
```
number_of_agents = 25;
```

```
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')
```

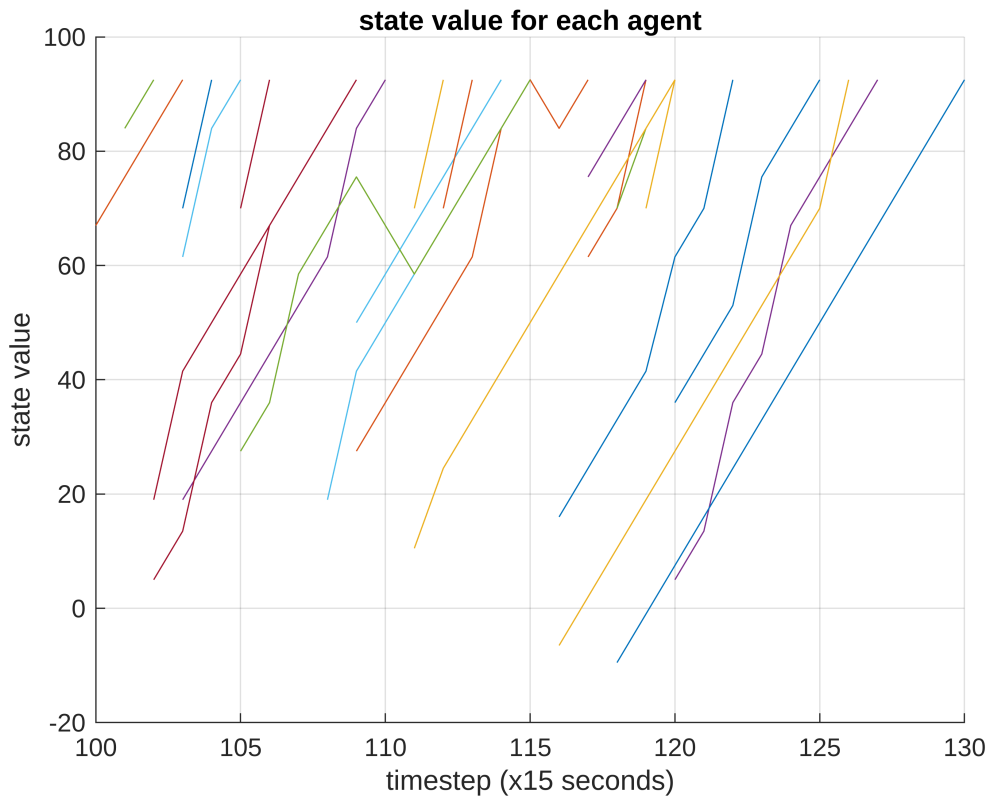



```
figure;
hold on
for agent_index = 1:number_of_agents

    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')
```