Contents


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%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Main Simulation Script for Resource Allocation Project with R Integration
% Using synthetic data to estimate parameters and compare to synthetic data
% The choice predictions is used to update survey inputs.
% This helps us validate initial human-centric choice predictions.
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
clc;
clear all;
```

Step 1: Import CSV Data

(reference apolloMain_5 amd apolloMain_6 as example for data manipulation) biasData = readtable('user_choices.csv'); % Replace with the path to your data file disp('User bias data imported successfully.'); taskChoice_Data = readtable('user_choices.csv'); % Replace with the path to your data file disp('User task choice data imported successfully.');

```
robotChoice_Data = readtable('G:\My Drive\myResearch\Research Experimentation\Apollo\apollo\data\WarehouseRobot_Pairing_Data\test_pairing_data.csv');
disp('User robot choice data imported successfully.');

% Extract relevant data (modify based on your CSV structure)
% task_attributes = data{:, {'efficiency', 'speed', 'safety', 'durability', 'skill'}};

% Extract and organize robot states for all three alternatives
robot_states = struct();
attributes = {'energy','pace','safety','reliability','intelligence'};
for i = 1:3
    for attr = attributes
        robot_states.(['robot' num2str(i)]).(attr{1}) = ...
            robotChoice_Data.(['robot' num2str(i) attr{1}]);
    end
end

% Extract choice data and other metadata
choices = robotChoice_Data.choice;
participant_ids = robotChoice_Data.participantid;
trial_numbers = robotChoice_Data.trial;
stake_types = robotChoice_Data.staketype;
time_spent = robotChoice_Data.timespent;
```

```
User robot choice data imported successfully.
```

Step 2: R Bridge Implementation

```
disp('Initializing R bridge...');

% Configure paths
rscript_path = 'C:\Program Files\R\R-4.4.2\bin\x64\Rscript.exe';
r_script = 'G:\My Drive\myResearch\Research Experimentation\Apollo\apollo\example\DFT_Resource_Allocation.R';
csvFile = 'G:\My Drive\myResearch\Research Experimentation\Apollo\apollo\data\WarehouseRobot_Pairing_Data\test_pairing_data.csv';
outputDir = 'G:\My Drive\myResearch\Research Experimentation\Apollo\apollo\ResourceAllocation_Output';

% Verify installations
if ~isfile(rscript_path)
    error('Rscript.exe not found at: %s', rscript_path);
elseif ~isfile(r_script)
    error('R script not found at: %s', r_script);
elseif ~isfile(csvFile)
    error('Input CSV not found at: %s', csvFile);
elseif ~isfolder(outputDir)
    warning('Output folder does not exist, creating: %s', outputDir);
    mkdir(outputDir);
end

% Execute R with JSON output
try
    % Use proper argument formatting
    cmd = sprintf(['"%s" "%s" ', ...
```

```
                '-i "%s" -o "%s"'], ...
                rscript_path, r_script, csvFile, outputDir);

[status,result] = system(cmd);

    if status == 0
        % Handle output path (whether directory or file)
        if isfolder(outputDir)
            jsonFile = fullfile(outputDir, 'DFT_output.json');
        else
            jsonFile = outputDir;
        end

        % Parse JSON output
        if exist(jsonFile, 'file')
            jsonText = fileread(jsonFile);
            params = jsondecode(jsonText);

            % Extract parameters with validation
            %Boundedphi1, phi2 parameters
            phi1 = max(0, validateParam(params, 'phi1', 0.5)); % Ensure non-negative
            phi2 = min(max(0, validateParam(params, 'phi2', 0.8)), 1); % Constrain 0-1

            %Raw phi1, phi2 parameters
            %phi1 = validateParam(params, 'phi1', 0.5);
            %phi2 = validateParam(params, 'phi2', 0.8);
            tau = 1 + exp(validateParam(params, 'timesteps', 0.5));
            error_sd = min(max(0.1, validateParam(params, 'error_sd', 0.1)), 1); % still clip here

            % Extract attribute weights
            beta_weights = exp([
                params.b_energy;
                params.b_pace;
                params.b_safety;
                params.b_reliability;
                params.b_intelligence
            ]);

            % Get initial preferences from ASCs
            initial_P = [
                params.asc_1;
                params.asc_2;
                params.asc_3;
              %  0  % Control alternative1 has 0 initial preference
               % 0  % Control alternative2 has 0 initial preference
            ];

            disp('Estimated Parameters:');
            disp(['phi1: ', num2str(phi1)]);
            disp(['phi2: ', num2str(phi2)]);
            disp(['tau: ', num2str(tau)]);
            disp(['error_sd: ', num2str(error_sd)]);
            disp('Initial Preferences (from ASCs):');
            disp(initial_P');
        else
            error('R output file not found');
        end
    else
        error('R execution failed: %s', result);
    end
catch ME
    disp('Error during R execution:');
    disp(getReport(ME, 'extended'));
    [phi1, phi2, tau, error_sd] = getFallbackParams();
    beta_weights = [0.3; 0.2; 0.4]; % Default weights ; 0.1; 0.5
    initial_P = zeros(3,1); % Neutral initial preferences
end
```

```
Initializing R bridge...
```

Step 3: MDFT Formulation to Calculate Preference Dynamics

(MDFT calculations based on estimated parameters)

```
%current_trial = 1; % Analyze first trial (can be looped later)

num_trials = size(robotChoice_Data, 1);  % Assuming each row is a trial
```

```
for current_trial = 1:num_trials
    % Extract data for the current trial
    trial_data = robotChoice_Data(current_trial, :);

% Create M matrix from current trial's attributes
M = [
    robotChoice_Data.robot1energy(current_trial), ...
    robotChoice_Data.robot1pace(current_trial), ...
    robotChoice_Data.robot1safety(current_trial), ...
    robotChoice_Data.robot1reliability(current_trial), ...
    robotChoice_Data.robot1intelligence(current_trial);

    robotChoice_Data.robot2energy(current_trial), ...
    robotChoice_Data.robot2pace(current_trial), ...
    robotChoice_Data.robot2safety(current_trial), ...
    robotChoice_Data.robot2reliability(current_trial), ...
    robotChoice_Data.robot2intelligence(current_trial);

    robotChoice_Data.robot3energy(current_trial), ...
    robotChoice_Data.robot3pace(current_trial), ...
    robotChoice_Data.robot3safety(current_trial), ...
    robotChoice_Data.robot3reliability(current_trial), ...
    robotChoice_Data.robot3intelligence(current_trial);

  %  0.1*ones(1,5) % Control alternative1

   % 0.9*ones(1,5) % Control alternative2
];

% Normalize beta weights
beta = beta_weights ./ sum(abs(beta_weights));

% Calculate DFT dynamics with initial preferences
[E_P, V_P, probs, P_tau] = calculateDFTdynamics(...
    phi1, phi2, tau, error_sd, beta, M, initial_P);

% Display results
disp('=== Current Trial Analysis ===');
disp(['Trial: ', num2str(current_trial)]);
disp(['Participant: ', num2str(participant_ids(current_trial))]);
disp(['Actual Choice: Robot ', num2str(choices(current_trial))]);

disp('M matrix (alternatives × attributes):');
disp(array2table(M, ...
    'RowNames', {'Robot1','Robot2','Robot3'}, ...
    'VariableNames', attributes)); %,'Control Alt1','Control Alt2'

% Create comparison table
result_table = table(probs, 'VariableNames', {'Probability'}, ...
                    'RowNames', {'Robot1','Robot2','Robot3'});
disp('Choice Probability Distribution:'); %,'Control1','Control2'
disp(result_table);

% Display DFT results with prediction
disp('DFT Results:');
disp(['E_P: ', num2str(E_P', '%.2f  ')]);
disp(['Choice probabilities: ', num2str(probs', '%.3f  ')]);
[~, predicted_choice] = max(probs); % Get index of highest probability
disp(['Predicted choice: Robot ', num2str(predicted_choice)]);
disp(['Actual choice: Robot ', num2str(choices(current_trial))]);
disp(' ');

% Display match/mismatch
if predicted_choice == choices(current_trial)
    disp('✓ Prediction matches actual choice');
else
    disp('✗ Prediction differs from actual choice');
end


% Plot preference evolution
figure;
plot(0:tau, P_tau);
xlabel('Preference Step (\tau)');
ylabel('Preference Strength');
legend({'Robot1','Robot2','Robot3'}); %,'C.Alt1', 'C.Alt2'
title(sprintf('Preference Evolution (Trial %d)', current_trial));
grid on;
```

```
end
%{
%% Step 4: Solve Equilibrium Function
% Ensure DFT outputs match expected dimensions
assert(length(E_P) == 5, 'DFT must return 5 alternatives');
assert(isequal(size(V_P), [5 5]), 'DFT covariance must be 5x5');

% Use DFT outputs for equilibrium calculation
Ep_mins = E_P;       % 4×1 expected preferences from DFT
Varp_mins = V_P;     % 4×4 preference covariance from DFT
% using robot attribute to map to product the robot can build type A vs
% type B. this is made using each robot attribute.
% 5 robot produce 2 things. each trial outputs x_mins as 10x1
x_mins = robot_production_capacity(M); % 10×1 robot state vector could recursive for each neighboring robot

% Call equilibrium solver
solutions = solve_equilibrium(Ep_mins, Varp_mins, x_mins);

% Extract solutions (works with both old and new versions)
if isfield(solutions, 'x')
    % Old version field names
    P_final = solutions.x;
    E_P_eq = solutions.lambda;
    V_P_eq = solutions.mu_vec;
else
    % New version field names
    P_final = solutions.P_final;
    E_P_eq = solutions.E_P_eq;
    V_P_eq = solutions.V_P_eq;
end

% Display results
disp('=== Equilibrium Results ===');
disp(['Final Preferences (P_final): ', num2str(P_final')]);
disp(['Expected Preferences (E_P_eq): ', num2str(E_P_eq')]);
disp(['Preference Variance (V_P_eq diagonal): ', num2str(V_P_eq')]);

%% Step 5: Output Results
disp('Saving results to CSV...');
output_table = table(E_P, V_P, P_final, ...
                     'VariableNames', {'ExpectedPreference', 'VariancePreference', 'FinalPreferences'});
writetable(output_table, 'results.csv');
disp('Results saved successfully!');
%}
```

```
=== Current Trial Analysis ===
Trial: 1
Participant: 1001
Actual Choice: Robot 2
M matrix (alternatives × attributes):
              energy    pace    safety    reliability    intelligence
              ______    ____    ______    ___________    ____________

    Robot1     0.65     0.55      0.7          0.6            0.58
    Robot2     0.75     0.45      0.8         0.65            0.62
    Robot3      0.5      0.6     0.65         0.55             0.5

Choice Probability Distribution:
              Probability
              ___________

    Robot1    0.00086705
    Robot2       0.99913
    Robot3    1.6559e-06

DFT Results:
E_P: -0.03   0.67  -0.66
Choice probabilities: 0.001  0.999  0.000
Predicted choice: Robot 2
Actual choice: Robot 2

✓ Prediction matches actual choice
=== Current Trial Analysis ===
Trial: 2
Participant: 1001
Actual Choice: Robot 1
M matrix (alternatives × attributes):
              energy    pace    safety    reliability    intelligence
```

```
              ______    ____   ______    ___________    ____________

    Robot1     0.55     0.45      0.6          0.5              0.48
    Robot2      0.7     0.35     0.75          0.6              0.57
    Robot3     0.45     0.55      0.6          0.5              0.45

Choice Probability Distribution:
              Probability
              ___________

    Robot1    4.7386e-08
    Robot2        0.9996
    Robot3    0.00039935

DFT Results:
E_P: -0.87   0.82   0.04
Choice probabilities: 0.000  1.000  0.000
Predicted choice: Robot 2
Actual choice: Robot 1

✗ Prediction differs from actual choice
=== Current Trial Analysis ===
Trial: 3
Participant: 1001
Actual Choice: Robot 3
M matrix (alternatives × attributes):
              energy    pace    safety    reliability    intelligence
              ______    ____    ______    ___________    ____________

    Robot1      0.6      0.5     0.65         0.55              0.53
    Robot2     0.65      0.4      0.7         0.55               0.6
    Robot3     0.55     0.65      0.7          0.6              0.55

Choice Probability Distribution:
              Probability
              ___________

    Robot1     2.689e-11
    Robot2    1.7535e-12
    Robot3             1

DFT Results:
E_P: -0.73  -1.00   1.71
Choice probabilities: 0.000  0.000  1.000
Predicted choice: Robot 3
Actual choice: Robot 3

✓ Prediction matches actual choice
=== Current Trial Analysis ===
Trial: 4
Participant: 1002
Actual Choice: Robot 2
M matrix (alternatives × attributes):
              energy    pace    safety    reliability    intelligence
              ______    ____    ______    ___________    ____________

    Robot1     0.7      0.6      0.75         0.65              0.63
    Robot2     0.8      0.5      0.85          0.7              0.67
    Robot3     0.6      0.7      0.75         0.65               0.6

Choice Probability Distribution:
              Probability
              ___________

    Robot1    0.00010438
    Robot2       0.12028
    Robot3       0.87962

DFT Results:
E_P: -0.54   0.16   0.36
Choice probabilities: 0.000  0.120  0.880
Predicted choice: Robot 3
Actual choice: Robot 2

✗ Prediction differs from actual choice
=== Current Trial Analysis ===
Trial: 5
Participant: 1002
Actual Choice: Robot 1
```

M matrix (alternatives × attributes):

	energy	pace	safety	reliability	intelligence
Robot1	0.5	0.4	0.55	0.45	0.43
Robot2	0.6	0.3	0.65	0.5	0.52
Robot3	0.4	0.5	0.55	0.45	0.4

Choice Probability Distribution:

	Probability
Robot1	0.0001041
Robot2	0.12263
Robot3	0.87727

DFT Results:
E_P: -0.54   0.16   0.36
Choice probabilities: 0.000 0.123 0.877
Predicted choice: Robot 3
Actual choice: Robot 1

✗ Prediction differs from actual choice
=== Current Trial Analysis ===
Trial: 6
Participant: 1002
Actual Choice: Robot 3
M matrix (alternatives × attributes):

	energy	pace	safety	reliability	intelligence
Robot1	0.75	0.65	0.8	0.7	0.68
Robot2	0.85	0.55	0.9	0.75	0.73
Robot3	0.65	0.75	0.8	0.7	0.65

Choice Probability Distribution:

	Probability
Robot1	0.00010432
Robot2	0.12074
Robot3	0.87915

DFT Results:
E_P: -0.54   0.16   0.36
Choice probabilities: 0.000 0.121 0.879
Predicted choice: Robot 3
Actual choice: Robot 3

✓ Prediction matches actual choice
=== Current Trial Analysis ===
Trial: 7
Participant: 1003
Actual Choice: Robot 2
M matrix (alternatives × attributes):

	energy	pace	safety	reliability	intelligence
Robot1	0.58	0.48	0.63	0.53	0.51
Robot2	0.68	0.38	0.73	0.58	0.61
Robot3	0.48	0.58	0.63	0.53	0.48

Choice Probability Distribution:

	Probability
Robot1	0.00010404
Robot2	0.1231
Robot3	0.87679

DFT Results:
E_P: -0.54   0.17   0.36
Choice probabilities: 0.000 0.123 0.877
Predicted choice: Robot 3
Actual choice: Robot 2

✗ Prediction differs from actual choice
=== Current Trial Analysis ===
Trial: 8

```
Participant: 1003
Actual Choice: Robot 1
M matrix (alternatives × attributes):
              energy    pace    safety    reliability    intelligence
              ______    ____    ______    ___________    ____________

    Robot1     0.62     0.52     0.67        0.57            0.55
    Robot2     0.72     0.42     0.77        0.62            0.65
    Robot3     0.52     0.62     0.67        0.57            0.52

Choice Probability Distribution:
              Probability
              ___________

    Robot1    0.00010404
    Robot2        0.1231
    Robot3       0.87679

DFT Results:
E_P: -0.54   0.17   0.36
Choice probabilities: 0.000  0.123  0.877
Predicted choice: Robot 3
Actual choice: Robot 1

✗ Prediction differs from actual choice
=== Current Trial Analysis ===
Trial: 9
Participant: 1003
Actual Choice: Robot 3
M matrix (alternatives × attributes):
              energy    pace    safety    reliability    intelligence
              ______    ____    ______    ___________    ____________

    Robot1     0.67     0.57     0.72        0.62             0.6
    Robot2     0.77     0.47     0.82        0.67             0.7
    Robot3     0.57     0.67     0.72        0.62            0.57

Choice Probability Distribution:
              Probability
              ___________

    Robot1    0.00010404
    Robot2        0.1231
    Robot3       0.87679

DFT Results:
E_P: -0.54   0.17   0.36
Choice probabilities: 0.000  0.123  0.877
Predicted choice: Robot 3
Actual choice: Robot 3

✓ Prediction matches actual choice
=== Current Trial Analysis ===
Trial: 10
Participant: 1004
Actual Choice: Robot 2
M matrix (alternatives × attributes):
              energy    pace    safety    reliability    intelligence
              ______    ____    ______    ___________    ____________

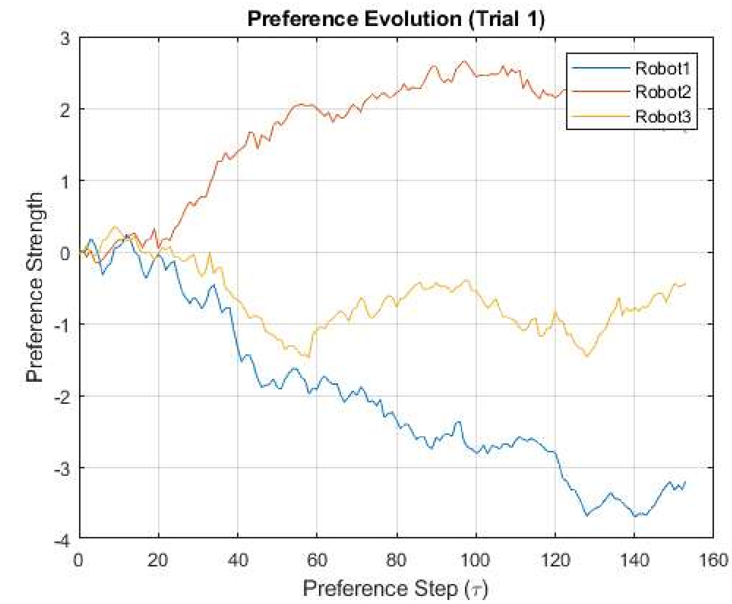
    Robot1     0.53     0.43     0.58        0.48            0.46
    Robot2     0.63     0.33     0.68        0.53            0.56
    Robot3     0.43     0.53     0.58        0.48            0.43

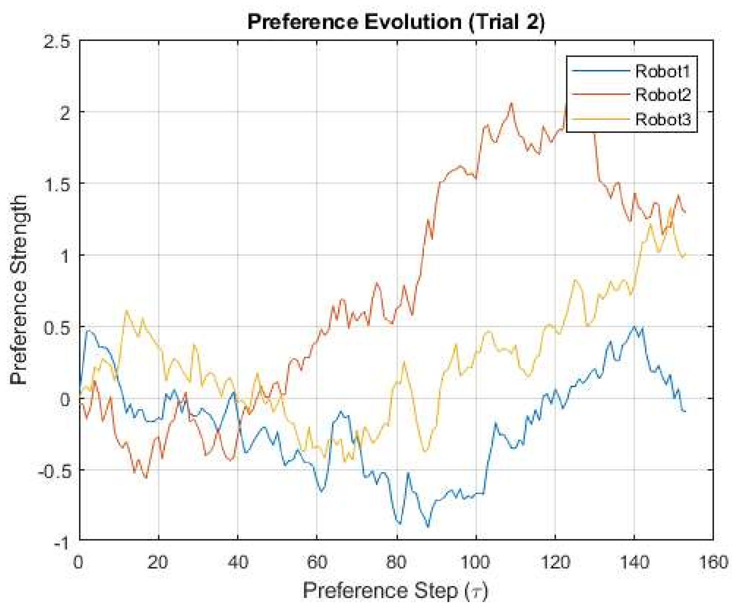
Choice Probability Distribution:
              Probability
              ___________

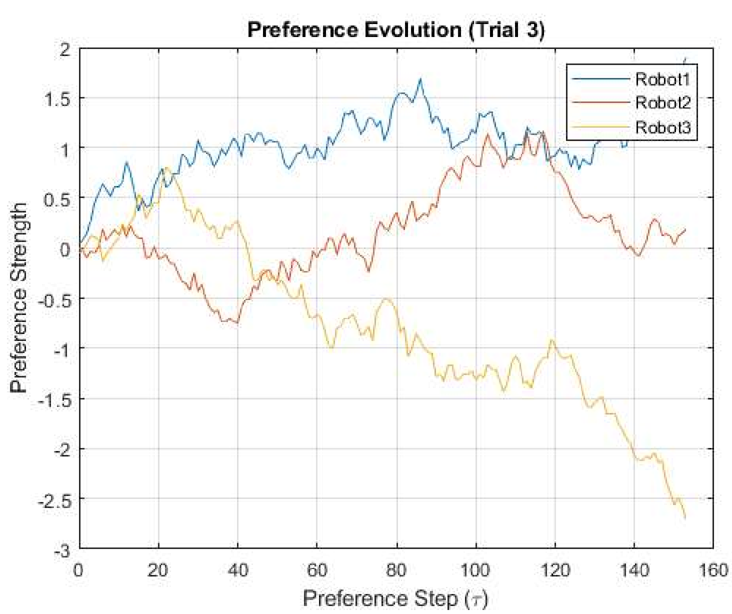
    Robot1    0.00010404
    Robot2        0.1231
    Robot3       0.87679

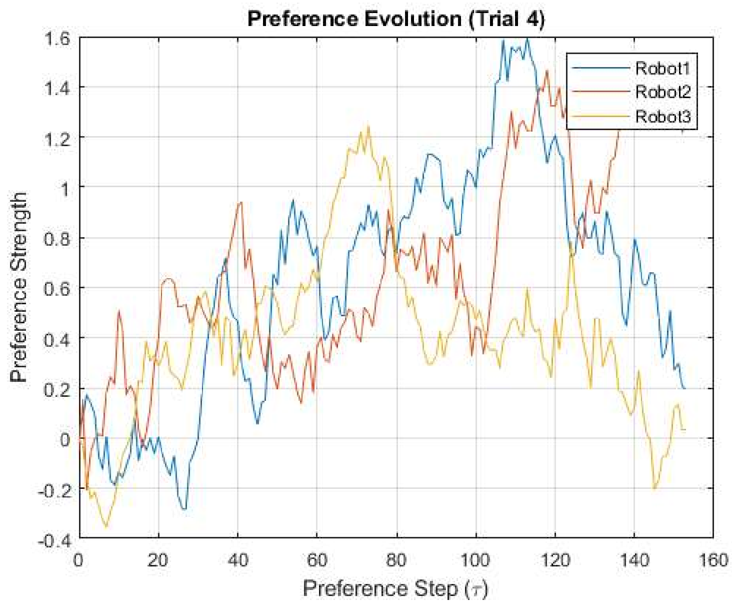
DFT Results:
E_P: -0.54   0.17   0.36
Choice probabilities: 0.000  0.123  0.877
Predicted choice: Robot 3
Actual choice: Robot 2

✗ Prediction differs from actual choice
```

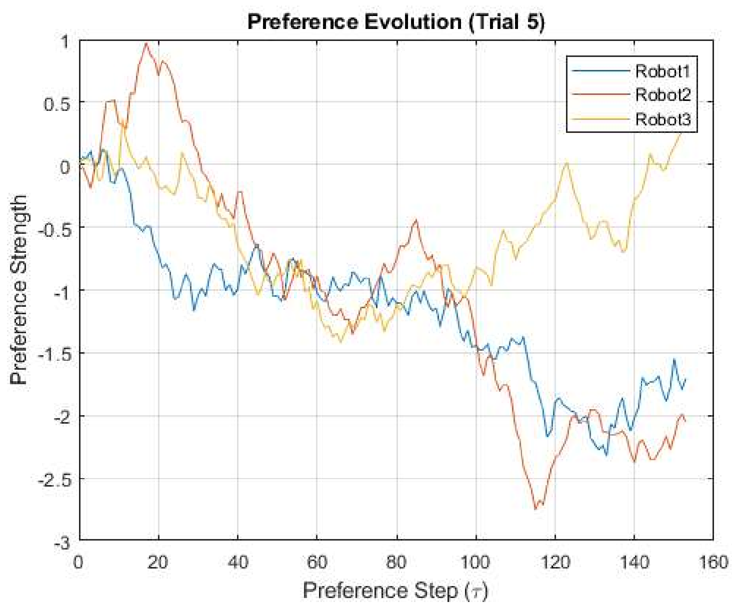

Preference Evolution (Trial 1)
Robot1
Robot2
Robot3
Preference Strength
Preference Step (τ)


Preference Evolution (Trial 2)
Robot1
Robot2
Robot3
Preference Strength
Preference Step (τ)

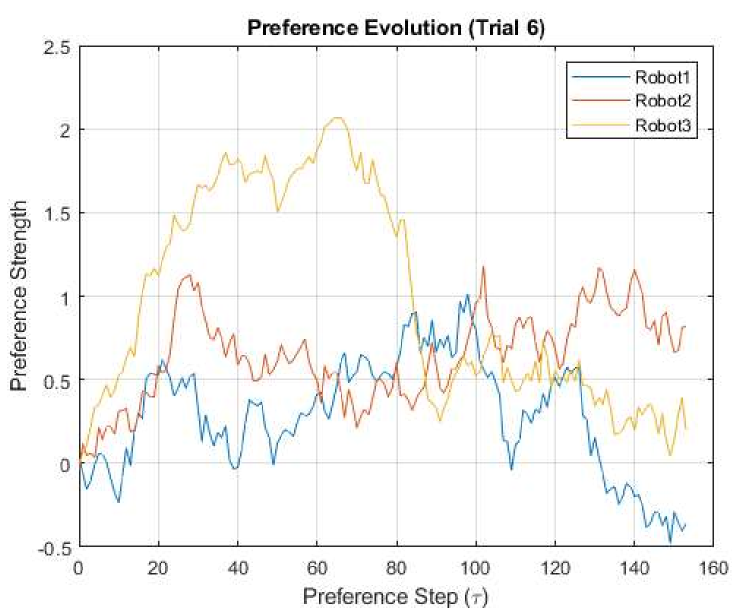

Preference Evolution (Trial 3)
Robot1
Robot2
Robot3
Preference Strength
Preference Step (τ)



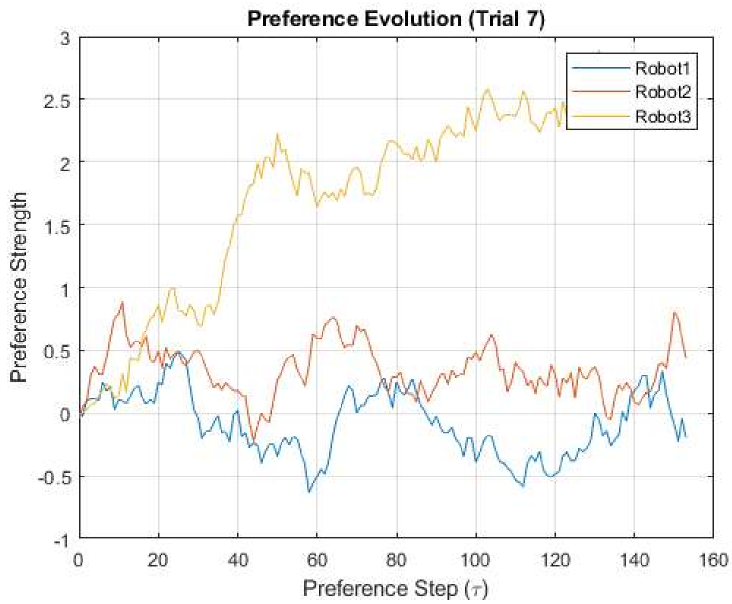
Preference Evolution (Trial 4)
Robot1
Robot2
Robot3
Preference Strength
Preference Step (τ)



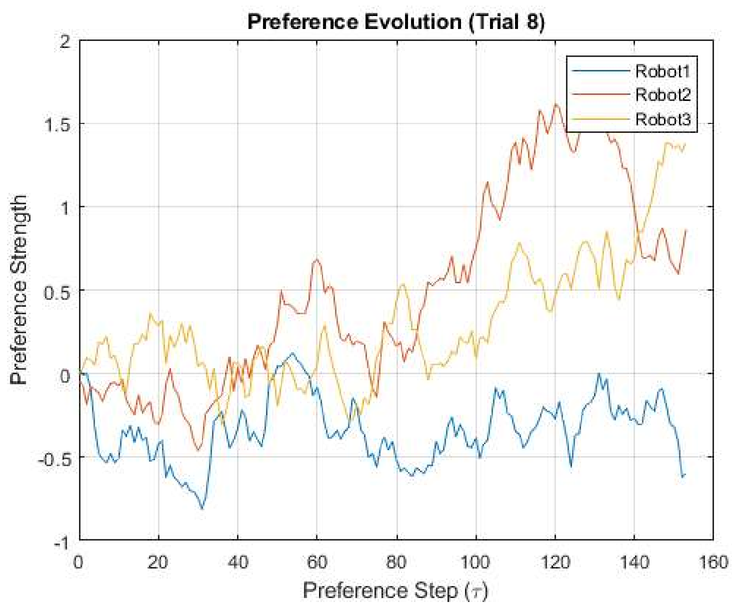
Preference Evolution (Trial 5)
Robot1
Robot2
Robot3
Preference Strength
Preference Step (τ)



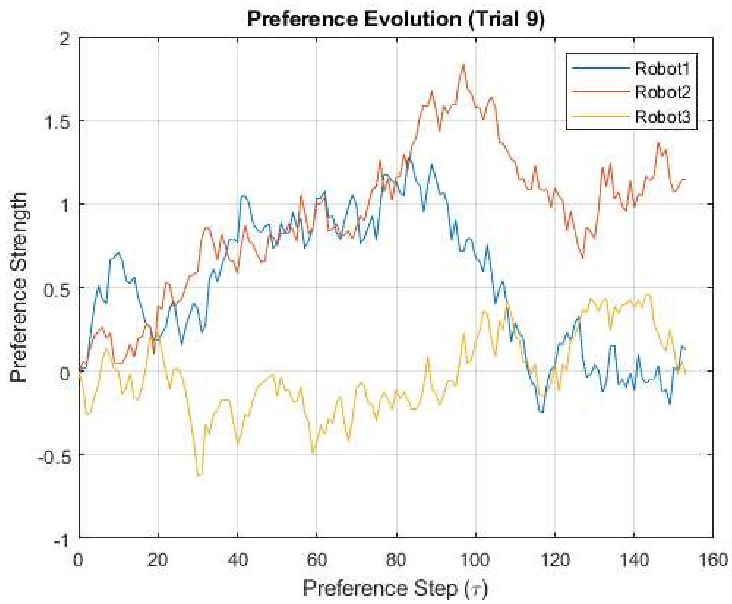
Preference Evolution (Trial 6)
Robot1
Robot2
Robot3
Preference Strength
Preference Step (τ)

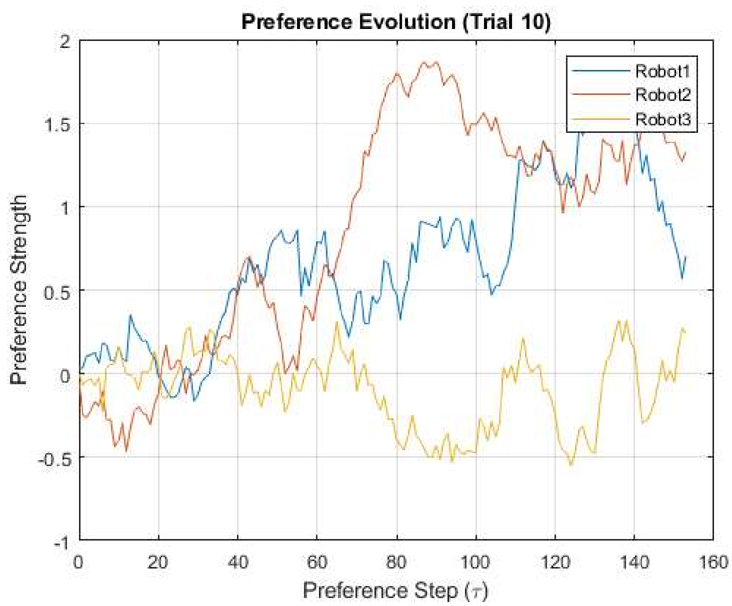


Preference Evolution (Trial 7)
Robot1
Robot2
Robot3
Preference Strength
Preference Step (τ)



Preference Evolution (Trial 8)
Robot1
Robot2
Robot3
Preference Strength
Preference Step (τ)





Helper Functions

```
function param = validateParam(params, name, default)
    if isfield(params, name) && isnumeric(params.(name))
        param = params.(name);
    else
        warning('Using default for %s', name);
        param = default;
    end
end

function [phi1, phi2, tau, error_sd] = getFallbackParams()
    phi1 = 0.5;
    phi2 = 0.8;
    tau = 10;
    error_sd = 0.1;
    warning('Using default parameters');
end
```

```
Estimated Parameters:
phi1: 0.3708
phi2: 0
tau: 153.1703
error_sd: 0.1
Initial Preferences (from ASCs):
```

```
    0.0312   -0.0471         0
```

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