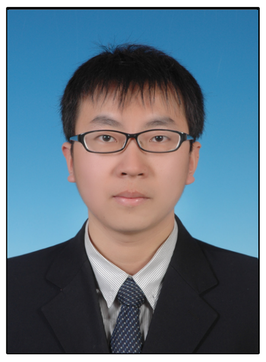
Co-design of Dynamic Real-Time Scheduling and Cooperative Control for Human-Agent Collaboration Systems Based on Mutual Trust



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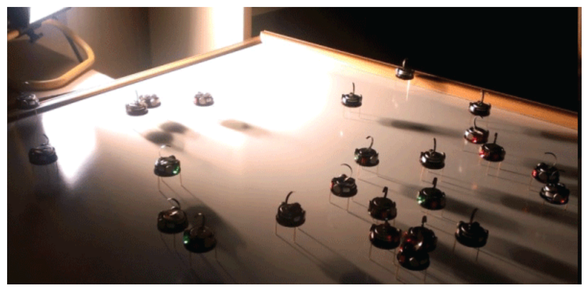
Motivation

(Semi)autonomous agents, like UAVs and UGVs, have been widely used for military and civilian application. However, current approaches are limited to multiple human operators controlling a single (semi)autonomous agent. The high level of manpower required to operate only one (semi)autonomous agent inevitably leads to high labor costs as well as human errors. To overcome these drawbacks, we conduct this project.



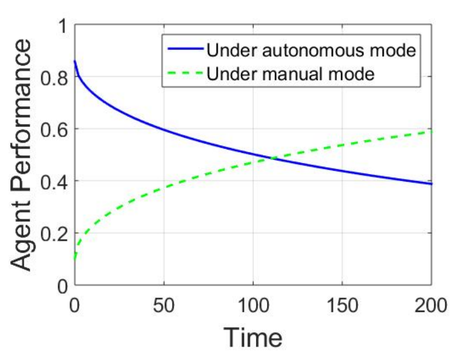
Model Setup

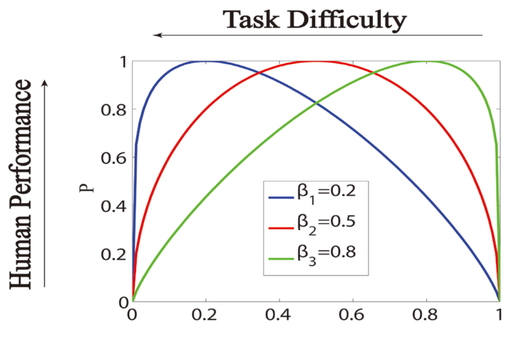
- Trust model
  - $T_{H-A}(k) = A_1 T_{H-A}(k-1) + B_1 P_A(k) - B_2 P_A(k-1) + D_1 F_A(k) - D_2 F_A(k-1)$

    Agent Performance / Agent Fault
  - $T_{A-H}(k) = A_2 T_{A-H}(k-1) + C_1 P_H(k) - C_2 P_H(k-1) + E_1 F_H(k) - E_2 F_H(k-1)$

    Human Performance / Human Fault
- Performance model
  - agent performance
    - $P_{n,A}(k) = \begin{cases} (1-k_{n,A})P_{n,A}(k-1) + k_{n,A}P_{n,A,min}, (autonomous\ mode) \\ (1-k_{n,H})P_{n,A}(k-1) + k_{n,H}P_{n,A,max}, (manual\ mode) \end{cases}$
  - human performance
    - $P_H(k) = (P_{H,max} - P_{H,min})(\frac{r(k)}{\beta})^{\beta}(\frac{1-r(k)}{1-\beta})^{1-\beta} + P_{H,\min}$

      Utilization Ratio / Task difficulty

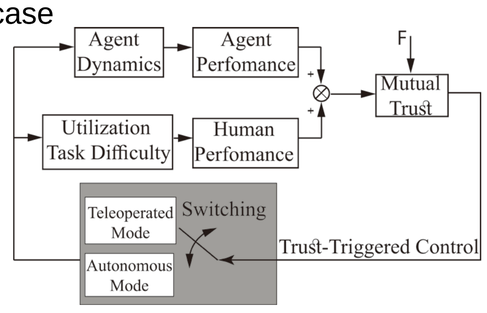




Control Design

- Switching Control
  - applied in **ONE** human and **MULTIPLE** agents case
    - $u(t) = \begin{cases} 1, & T(t) > T_u \\ 0, & T(t) \le T_l \\ u(t-1), & otherwise \end{cases}$

      Upper Limit and lower limit of the trust region



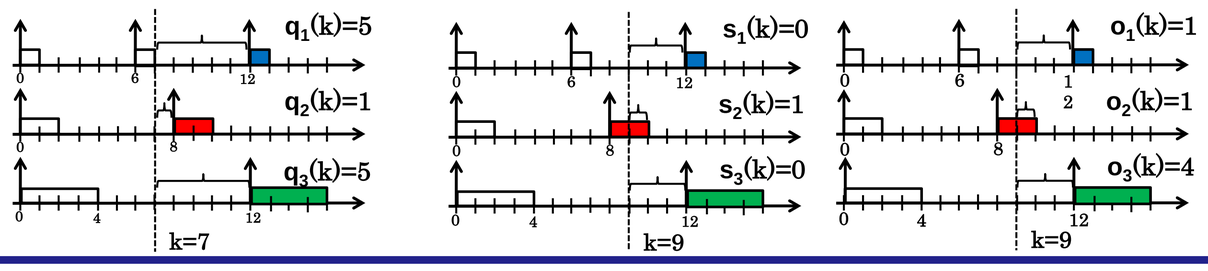
- Formation Control
  - applied in **MULTIPLE** human and **SWARM** agents case
    - $u_i(t) = \sum_{j \in N_j(t)} \frac{Rd_j - (q_i - q_j)}{\sqrt{(q_i - q_j)^T (q_i - q_j)}}$, where $q_i \in R^2$ stands for the position of an agent

      Desired distance between two swarms

Scheduling Method

- Dynamic timing model

  Dynamic Arrive Time, **Q(k)** Residue Time, **s(k)** Response Time, o**(k)**



- Schedulability Test

Algorithm 1: Schedulability test

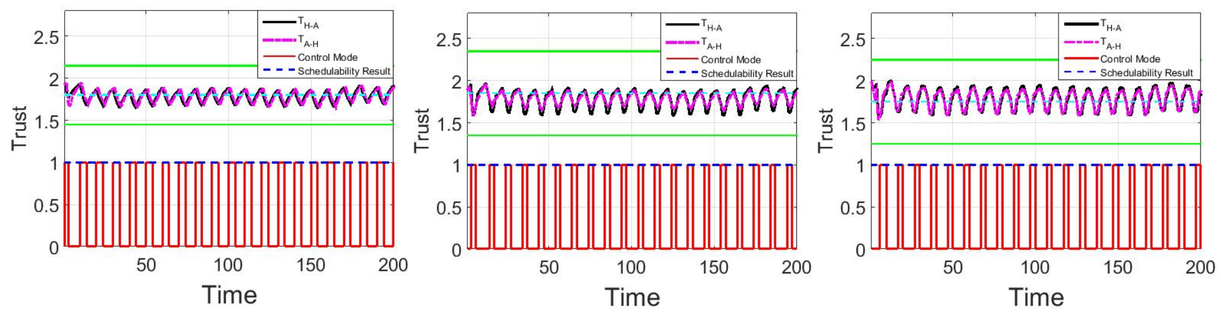
Data: L_n, $\{q_n(k), s_n(k), o_n(k)\}_{n=1}^N$

Result: $\{DS_n\}_{n=1}^N$

if $q_n(k_{w+1}-1) == 1$ **then**
  if $o_n(k_{w+1}-1) < L_n - 1$ **then**
    $ds_n = 1$ within the subinterval $[k_w, k_{w+1}]$;
  else if $o_n(k_{w+1}-1) = L_n - 1$ and $s_n(k_{w+1}-1) = 0$ or 1 **then**
    $ds_n = 1$ within the subinterval $[k_w, k_{w+1}]$;
  else
    $ds_n = 0$ within the subinterval $[k_w, k_{w+1}]$;
else
  $ds_n = ds_n$ within the subinterval $[k_w, k_{w+1}]$;
$DS_n = \{DS_n, ds_n\}$;
return $\{DS_n\}_{n=1}^N$;

Simulation Results

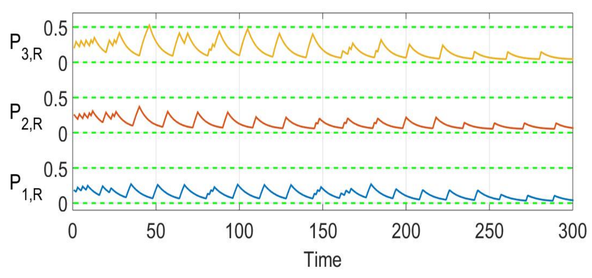
- Trust



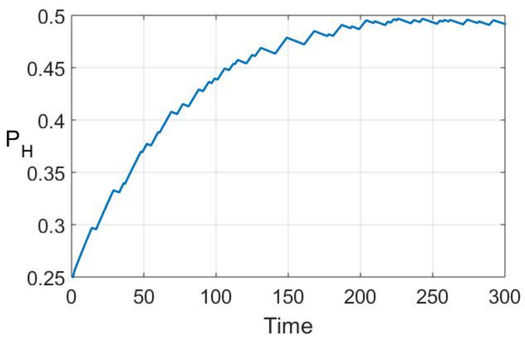
Mutual Trust between one Human and different Agents

- Performance

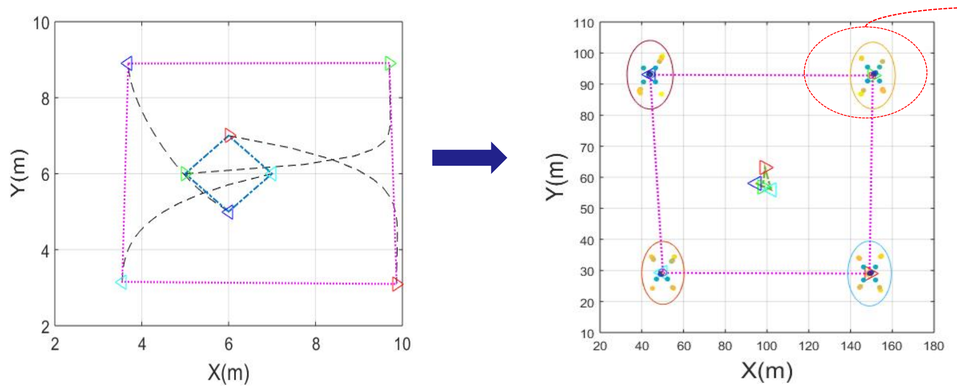
Scheduled Agent Performance



Human Performance



- Network under formation control



Conclusions

In this project, we develop a schedulability test algorithm based human-agent collaboration systems using trust model and the dynamic timing model to avoid both over- and under-trust. Meanwhile, the formation control we design is also incorporated in the swarm systems to enable several large-scale agent teams to simultaneously reach navigational goals and avoid collisions. The simulation results show that our scheduling algorithm can guarantee the mutual trust level in the desired trust regions.

For more information, please contact

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