Receding Horizon Control of Multiagent Systems with Competitive Dynamics

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MOTIVATIONS

CIVIL AND MILITARY

CROWD MODELING

Aerial Pursuer

Evader

Ground Pursuers
PROJECT OBJECTIVES

RECEDING HORIZON CONTROL or POTENTIAL-BASED CONTROL?

POTENTIAL:
- Simple
- Effective

RHC:
- Predictive Approach
- Performances Quantification

Flocking Bats - Batman Returns (1992)

Wildbeest Stampede - The Lion King (1994)
CONTRIBUTION

- RHC MODELING FOR TWO AGENTS (1 PURSUER, 1 EVADER)
- PREDICTION
- CONTROL
- EXPERIMENTAL RESULTS
**RHC APPROACH**

**RHC ALGORITHM:**
1. Solve an **optimal control problem** over \([0, N]\)
2. \([u_t, u_{t+1}, \ldots, u_{t+N-1}] \rightarrow u_t\)
3. New Measure
4. Go to step

\[
J(x, u) = x_N^T S x_N + \sum_{t=0}^{N-1} x_t^T Q x_t + u_t^T R u_t
\]
Agents’ dynamics: \[ s^i_{t+1} = s^i_t + u^i_t, \quad i = 1, 2, \]

Desired Cost Functions: \[
J_{i,j} = \sum_{k=1}^{N^i-1} \left( \| s^i_{t+k} - s^j_{t+k} \|_P^2 + ||u^i_{t+k}||_R^2 \right), \quad i \neq j,
\]

Used Cost Functions: \[
J_{i,j} = \sum_{k=1}^{N^i-1} \left( \| s^i_{t+k} - s^j_{t+k} \|_P^2 + ||u^i_{t+k}||_R^2 \right), \quad i \neq j,
\]

Control Laws: \[
u^i_t = \min_{u^i_t, u^i_{t+1}, \ldots, u^i_{t+N}} J_{i,j}(s, u, N)
\]
\[
u^j_t = \min_{u^j_t, u^j_{t+1}, \ldots, u^j_{t+N}} J_{j,i}(s, u, N)
\]
RESULTS

THEOREM: Consider the two agents described by the LTI discrete system, controlled using the RHC strategy, without any state and input constraints. We define the agents distance:

\[ e_{ij}^t = x_i^t - x_j^t \]

1) CONTROLLER STRUCTURE: 
(Linear Feedback)

\[ u_i^t = \alpha_i(p, r, N)(x_j^t - x_i^t - d_{ij}) \]
\[ u_j^t = \alpha_j(p, r, N)(x_i^t - x_j^t - d_{ji}) \]

A close form for \( \alpha \) been found, and it depends by \( p, r \) (the weight in the cost function) and by the control horizon \( N \). Moreover \( \alpha \in ]0,1[ \).

2) STEADY STATE BEHAVIOR:

\[ e_{ij} \rightarrow \frac{\alpha_j d_{ij} + \alpha_i (-d_{ji})}{\alpha_i + \alpha_j} \]

Cooperative: \( d_{ij} = -d_{ji} \rightarrow u_i^t = u_j^t = 0 \rightarrow \) Fixed position

Competitive: \( d_{ij} \neq -d_{ji} \rightarrow u_i^t, u_j^t = cost \rightarrow \) Convergence along a line
\[ J_{i,j} = \sum_{k=1}^{N_i - 1} (\| s^i_{t+k} - s^j_t + d^{ij}_t \|^2_{P^i} + \| u^i_{t+k} \|^2_{R^i}), \quad i \neq j, \]

Robber Cost Function: R small
Cop Cost Function: R big

Robber Cost Function: R big
Cop Cost Function: R small

VIDEO FRAMES
CHARACTERISTIC

- **Robots**: LEGO Mindstorms NXT
- **Control Computer**: MacBook Pro 13”
- **Vision System**: Microsoft LifeCam Studio
- **Communication**: Bluetooth
CONCLUSIONS

RESULTS:

• **Analytic solution** for the pursuit evasion games with RHC.

• **Experimental implementation** and verification of algorithm.

FUTURE RESEARCH:

• Scalability of our results to **larger teams** of agents.

• Inclusion of **estimators** in the algorithms (i.e. use of a ARMA model).