Problem
We consider cooperative control of robots involving two different testbed systems in remote locations in different time zones, with communication on the Internet. A dual-testbed design is developed involving real robots and remote network communication, performing a cooperative swarming algorithm based on a modified Morse Potential. We ran several experiments, with intentional packet loss, that illustrate the degradation of the results in the case of modest and severe packet loss.

Swarming algorithm
We use the Morse Potential based algorithm described in [1].
\[
\begin{align*}
\frac{dx_i}{dt} &= v_i \\
\frac{dv_i}{dt} &= (\alpha - \beta \|v_i\|^2) v_i - \nabla U(x_i) + \sum_{j=1}^{N} C_0 (v_j - v_i)
\end{align*}
\]
where \( U \) is the potential function, \( N \) is the total number of robots, \( y_i \) is the leader position, \( m_i \) refers to the robot mass, \( C_0 \) is the velocity alignment, \( C_l \) is the leader attraction potential, \( C_a \) and \( C_r \) are respectively the robot attraction and repulsion coefficients and \( l_a \) and \( l_r \) are the robot attraction and repulsion lengths, respectively.

Simulation without loss of information
Actuation rates for agents are low enough to accommodate any network delays.
Average transfer delays: 0.1240 (UC) and 0.1154 (UCLA) seconds;
Maximum transfer delays: 0.3-0.35 seconds

Influence of packet loss
The following figure shows the convergence behavior of individual agents (UC on the top row, UCLA on bottom) in three cases of packet loss: \( \geq 90\% \) (left), \( \sim 5-6\% \) (middle) and minimal packet loss (right). The black dots represent the packets that went through.

Future work
- Implementation on physical robots of the swarming algorithm across the IP network,
- Test different more complex algorithms involving cooperative behavior,
- Theoretically analyse the influence of packet loss (rate bounds) on global swarming behavior and convergence.

References

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