Robot swarming over the internet

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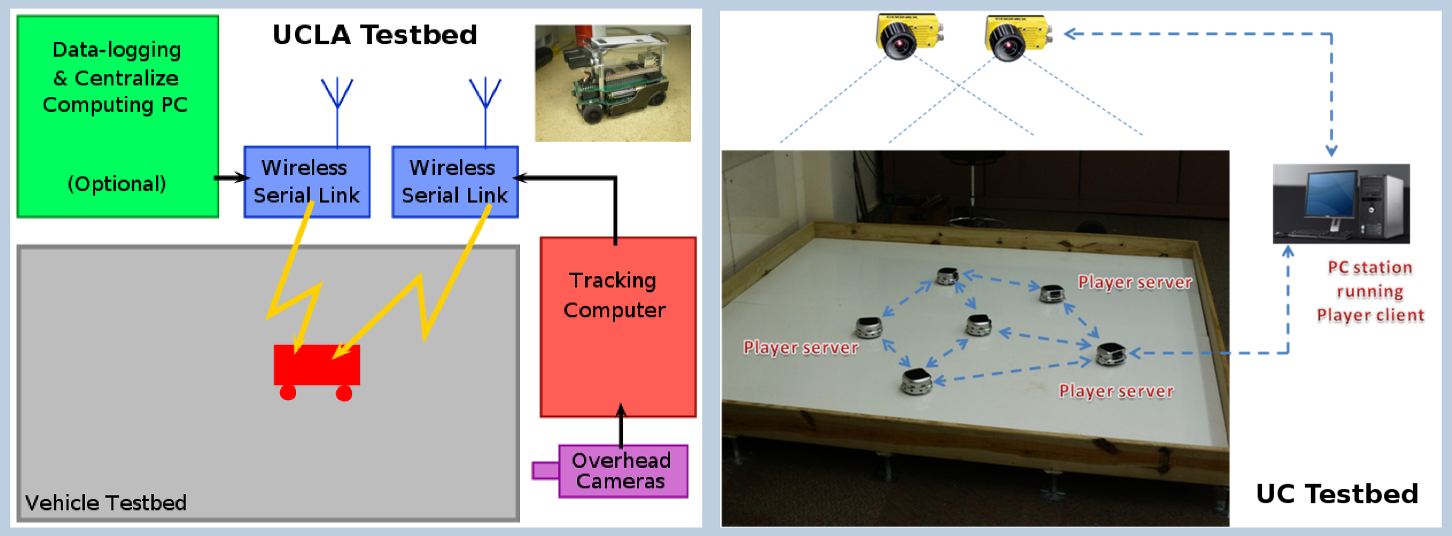
Problem

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.

Configuration and communications



Network communications are established, via the Matlab Instrument Control toolbox, between each Remote Terminal PC (RTPC) by using a TCP/IP protocol over a VPN through Internet. Data are sent in the following format:

$$(X_1\ X_2\ X_{N_p}\ Y_1\ Y_2\ Y_{N_p}\ V_{x_1}\ V_{x_2}\ V_{x_{N_p}}\ V_{y_1}\ V_{y_2}\ V_{y_{N_p}})$$

where $X_i, Y_i, V_{x_i}, V_{y_i}$ are the two dimensional Cartesian coordinates of $i-th$ robot and its velocity components respectively.

References

[1] W. Liu and Y.E. Taima and M.B. Short and A.L. Bertozzi, *Multi-scale Collaborative Searching and Swarming*, Proceedings of the 7th International Conference on Informatics in Control, Automation, and Robotics (ICINCO), Madeira, Portugal, 2010

[2] M. Gonzalez and X. Huang and B. Irvine and D.S. Hermina Martinez and C.H. Hsieh and Y.R. Huang and M.B. Short and A.L. Bertozzi, *A Third Generation Micro-vehicle Testbed for Cooperative Control and Sensing Strategies*, Proceedings of the 8th International Conference on Informatics in Control, Automation and Robotics(ICINCO), 2011

[3] A. Turan and S. Bogosyan and M. Gokasan, *Development of a Client-Server Communication Method for Matlab/Simulink Based Remote Robotics Experiments*, Proceedings of the IEEE International Symposium on Industrial Electronics, 2006

[4] Ming Li and Kejie Lu and Hua Zhu and Min Chen and Shiwen Mao and Prabhakaran, B., *Robot swarm communication networks: Architectures, protocols, and applications*, Proceedings of Communications and Networking in China, 162–166, Aug. 2008

[5] M. Sugisaka and D. Hazry, *User Interface in Web Based Communication for Internet Robot Control*, Proceedings of the International Conference on Control, Automation and Systems (ICCAS), 2005

Swarming algorithm

We use the Morse Potential based algorithm described in [1].

$$\frac{dx_i}{dt} = v_i$$

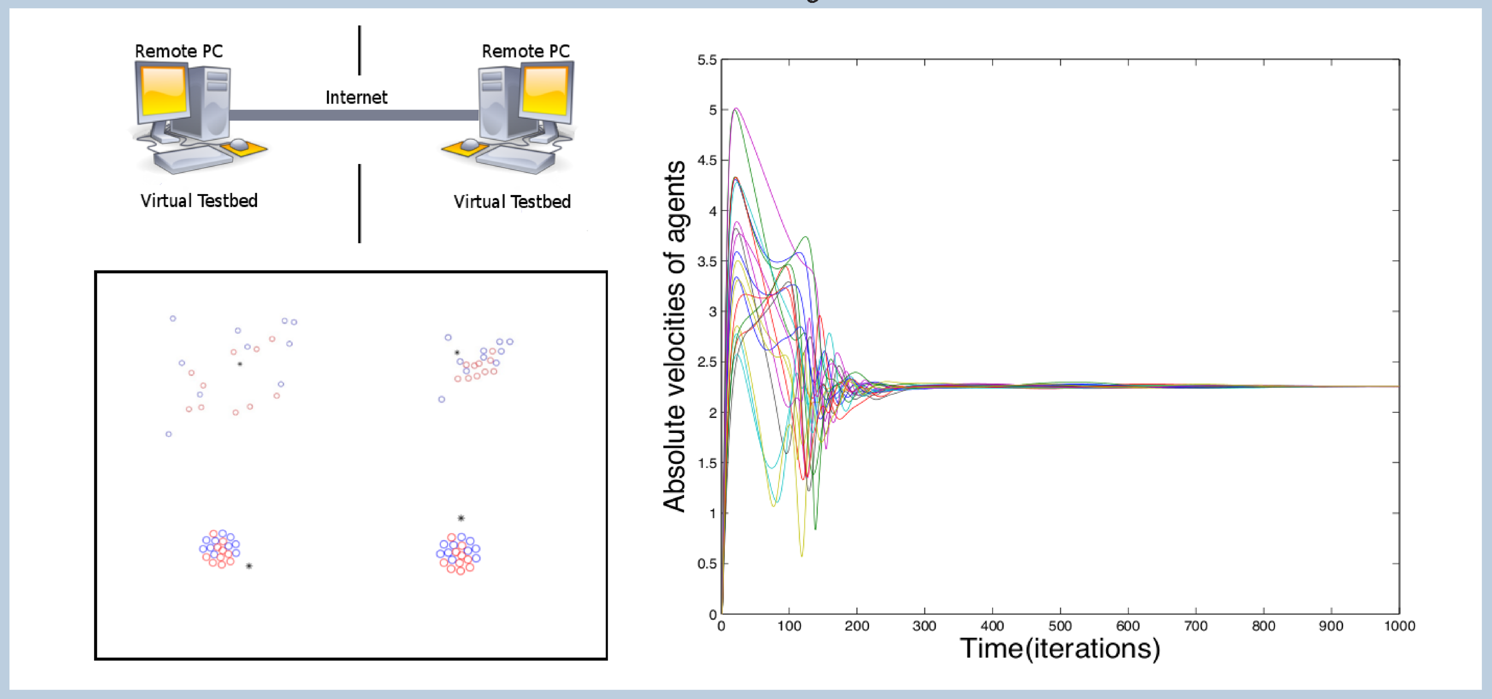
$$\frac{dv_i}{dt} = \left(\alpha - \beta \|v_i\|^2\right) v_i - \nabla U(x_i) + \sum_{j=1}^{N} C_0(v_j - v_i)$$

$$U(x_i) = \frac{1}{2} C_l (x_i - y)^2 + \sum_{j=1}^{N} \left(C_r e^{\frac{\|x_i - x_j\|}{l_r}} - C_a e^{\frac{\|x_i - x_j\|}{l_a}} \right)$$

where U is the potential function, N is the total number of robots, y is the leader position, m 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.

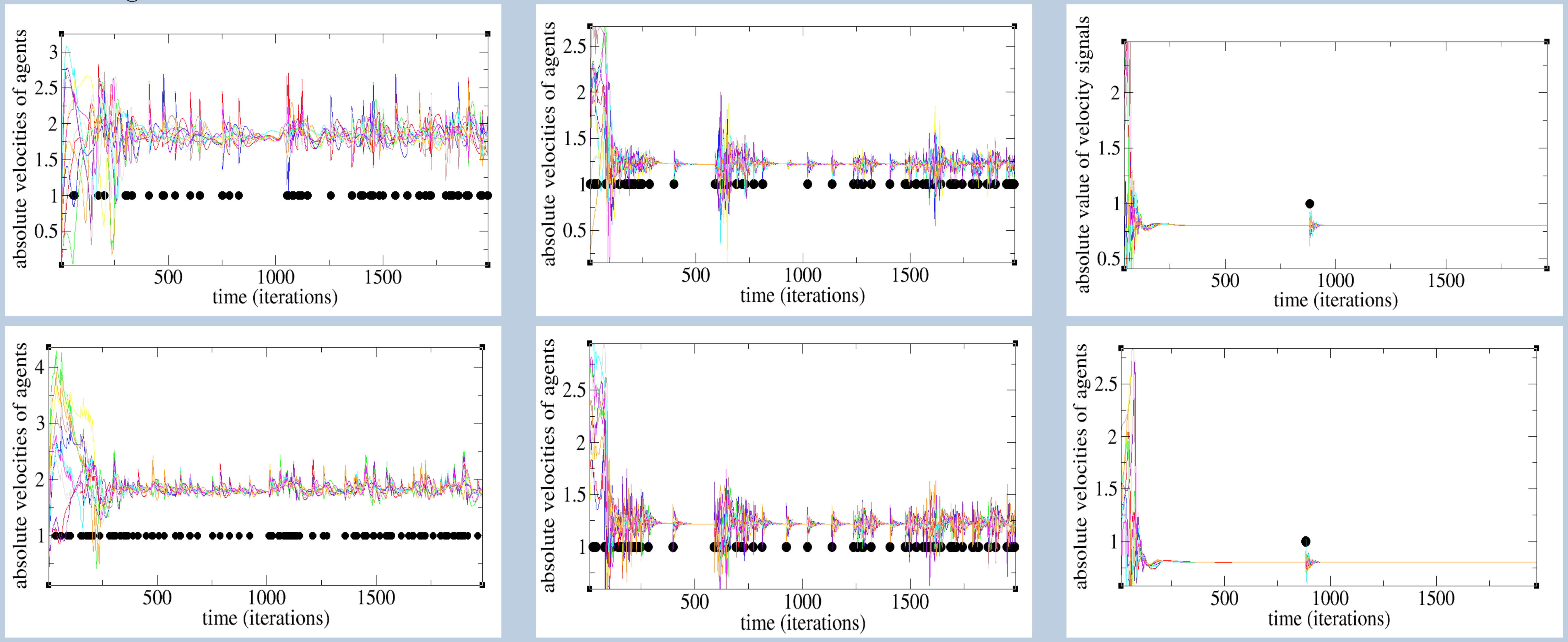
Simulation without loss of information

Actuation rates for agents are low enough to accomodate 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.

Acknowledgements

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