Linear Prediction in a Multi-Agent Environment

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Agents in an open and distributed environment can achieve their goals better and faster if they can predict future states of their environment. Previous works on predictive agents showed that very simple prediction strategies alone are not sufficient in order to deal with complex dynamics (Kephart, Hogg & Huberman 1990) and often took the way of developing a very specialized model in order to predict a highly dynamic model-environment (Hübler & Pines 1993). Regarding this tradeoff between accuracy and speed we argue that there might be situations where agents have to react in a real-time manner and are doing better by preferring speed over accuracy. Our agents applying *Linear Prediction* observe their environment as a series of time discrete events. This environment could be e.g. the number of agents using a resource at a certain time.

By using *Linear Prediction (LP)* we regard an agent as a filter which produces the prediction for the environmental state y_n at time step n from the P previous environmental states $y_{n-k}, k = 1, \ldots, P$:

$$y_n = \sum_{k=1}^{P} a_k y_{n-k} + \varepsilon_n$$

with the *LP-parameters* $a_k, k = 1, \ldots, P$ and ε_n being the prediction error for y_n.

It is the aim of an agent to adjust the LP-parameters in such a way that the *mean-square error* σ_ε^2 which is the expectation of $|\varepsilon_n|^2$ is minimized. This is achieved by using the correlation matrix:

$$\begin{bmatrix} R_y[0] & R_y[1] & \ldots & R_y[P] \\ R_y[-1] & R_y[0] & \ldots & R_y[P-1] \\ \vdots & \vdots & \vdots & \vdots \\ R_y[-P] & R_y[-P+1] & \ldots & R_y[0] \end{bmatrix} \begin{bmatrix} 1 \\ a_1 \\ \vdots \\ a_P \end{bmatrix} = \begin{bmatrix} \sigma_\varepsilon^2 \\ 0 \\ \vdots \\ 0 \end{bmatrix}$$

where an agent calculates the *correlations* $R_y[l], l = 0, \ldots, P$ from a number N_s of sampled events with a sample correlation function:

$$R_y[l] = \frac{1}{N_s - |l|} \sum_{n=0}^{N_s-1-|l|} y[n+|l|]y[n]; |l| < N_s.$$

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Observing single-agent performance in an environment modeled by a logistic map we find that the predictions are very accurate as long as the environment shows periodic oscillations. This is even true for multiple-step predictions and for a small N_s. The prediction error grows rapidly when the environmental dynamics shift towards the edge of chaos.

In a model of a heterogeneous environment multiple agents have to allocate resources competitively. Each agent associates a payoff function with each resource. This payoff function depends on the fraction of agents using the resource at that time. The agents use LP as well as more simple prediction mechanisms and random predictions. According to the number of agents using a resource at previous time steps an agent tries to predict and allocate the resource which promises to give the highest payoff. Oscillations which occur in this environment can be damped significantly if a certain number of agents apply LP. This leads to a more efficient use and allocation of resources.

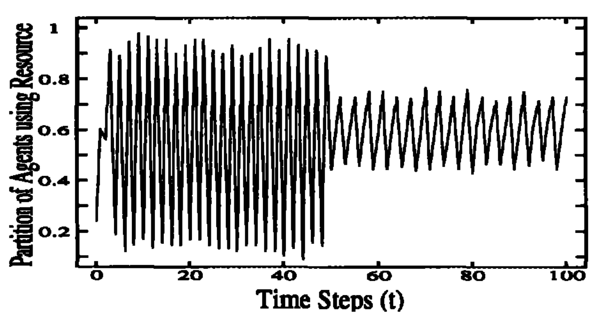

Figure 1: Resource allocation by simple and random predicting agents. From $t = 50$ agents use also LP.

References

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