insect_decision

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1 Introduction

insect_decision is a collection of numerical approximations of dynamical models of binary nest selection in social insects, as reported in Marshall et al. (2009). The program also includes a GUI allowing the user to modify parameters and visualize how doing so changes the behavior of the model; this is written using the open source QT framework. The approximations are based on the 4th order Runge-Kutta method.

2 The Usher-McClelland Model

The basic idea behind the Usher-McClelland model (figure 1) of binary decision making is to model the two options as neural activities. The activity for each option is increased by the input signal for that option, the activity is decreased by (i) inhibitory connections from the competing option, and (ii) leakage. The system is therefore modeled by:

$$\begin{aligned} \dot{y}_1 &= (I_1 + n_1) - y_1 k - y_2 w \\ \dot{y}_2 &= (I_2 + n_2) - y_2 k - y_1 w \end{aligned} \tag{1}$$

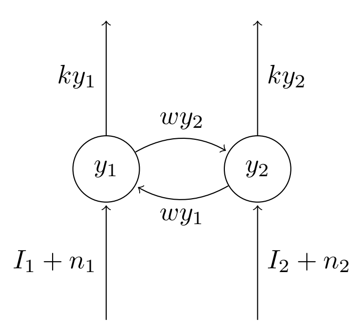

Figure 1: The Usher-McClelland model.

Where I_i is the input to option i, n_i is noise with mean 0.0 and a small standard deviation, k is the decay rate, and w is the weight between options.

3 The simplified Pratt Model

The simplified Pratt model is based on the following scenario: a colony of insects is looking to change from a source nest s to one of two alternatives y_1 and y_2. Insects discover each nest at a rate q_i; this is analogous to the input signals to the two neural activities in the Usher-McClelland model. Scouts from s will be attracted to y_1 and y_2 at these rates. Furthermore, insects already committed to a new nest can recruit (i.e., by tandem running) those from s at recruitment rates r'_1 and r'_2, up to the point where s is empty, at which point the number of recruited insects is zero. Insects also spontaneously wander off from each nest after they've been committed, returning to s; this is analogous to the leakage of the Usher-McClelland model. Finally, insects may also wander away from a nest only to end up in the competing nest – this is called 'direct transfer' between y_1 and y_2, and the transfer rates are r_1 and r_2. Letting n be noise terms with mean 0.0 and a small standard deviation, this yields the following model:

$$
\begin{aligned}
\dot{y}_1 =& (s - y_1 - y_2)(q_1 + n_{q_1}) \\
&+ y_1 r'_1(s) \\
&+ y_2(r_2 + n_{r_2}) \\
&- y_1(r_1 + n_{r_1}) \\
&- y_1(k_1 + n_{k_1}) \\
\dot{y}_2 =& (s - y_1 - y_2)(q_2 + n_{q_2}) \\
&+ y_2 r'_1(s) \\
&+ y_1(r_1 + n_{r_1}) \\
&- y_2(r_2 + n_{r_2}) \\
&- y_2(k_2 + n_{k_2})
\end{aligned}
\tag{2}
$$

Where $(s - y_1 - y_2)$ is the current population remaining in s, and $r'_i(s) = r'_i + n_{r'_1}$ if $s > 0$, and 0 otherwise.

Note that in the Usher-McClelland model, the activity of one ensemble inhibits the activity of the other. In the simplified Pratt model, however, the number of insects directly transferring from one nest to another is not a function of the number of insects in the nest receiving the new arrivals. That is, for example, the activity of y_i has no influence on how many insects from y_2 directly transfer to y_1 (and hence y_1 has no 'inhibitory' influence on the activity of y_2).

4 The simplified indirect Britton model

The simplified indirect Britton model is like the simplified Pratt model, except (i) there is no direct transfer between y_1 and y_2, and (ii) the number of ants recruited from s is modified by a factor of the current population of s (i.e., rather than recruit 0 or $y_1(r'_1 + n_{r'_1})$ ants at each time step, the new model recruits $y_1(s - y_1 - y_2)(r'_1 + n_{r'_1})$ ants). Since we are assuming the initial population is $s \geq 1$, this means more ants are typically recruited than in the Pratt model.

$$
\begin{aligned}
\dot{y}_1 =& (s - y_1 - y_2)(q_1 + n_{q_1}) \\
& + y_1(s - y_1 - y_2)(r'_1 + n_{r'_1}) \\
& - y_1(k_1 + n_{k_1}) \\
\dot{y}_2 =& (s - y_1 - y_2)(q_2 + n_{q_2}) \\
& + y_2(s - y_1 - y_2)(r'_2 + n_{r'_2}) \\
& - y_1(k_2 + n_{k_2})
\end{aligned}
\tag{3}
$$

5 The simplified direct Britton model

The simplified direct Britton model is nearly identical to the simplified indirect model. First, the rate at which recruits 'leak' back to s is no longer distinct for the two nests, and the noise term has been eliminated. Second and more importantly, there is now direct transfer between nests proportional to both the number of insects available to be recruited and the number available to do the recruiting. This term thus puts the model back on par with the Usher-McClelland model insofar as the activity of one option can suppress the activity of the other.

$$
\begin{aligned}
\dot{y}_1 =& (s - y_1 - y_2)(q_1 + n_{q_1}) \\
& + y_1(s - y_1 - y_2)(r'_1 + n_{r'_1}) \\
& - y_1 k \\
& + y_1 y_2(r_1 - r_2 + n_{r_1} - n_{r_2} \\
\dot{y}_2 =& (s - y_1 - y_2)(q_2 + n_{q_2}) \\
& + y_2(s - y_1 - y_2)(r'_2 + n_{r'_2}) \\
& - y_1 k \\
& - y_1 y_2(r_1 - r_2 + n_{r_1} - n_{r_2}
\end{aligned}
\tag{4}
$$

References

Marshall, James A. R. et al. (2009). "On optimal decision-making in brains and social insect colonies". In: *Journal of The Royal Society Interface*, rsif.2008.0511. ISSN: 1742-5689, 1742-5662. DOI: 10.1098/rsif.2008.0511.