CS-4752
Introduction to Computational Intelligence

November 10, 2011

Final Project

• The project proposal is due on November 15.
• The final project is due on December 16.
• While working on your proposal, think about problem modeling: what are the variables, representation, constraints and fitness function. If you can not work out these details in your proposal, you are likely to have problem finishing your project on time.
• I will post the project report format on the class website today.

Division of Labor


Division of Labor Mechanisms

• How does the colony allocates tasks for each ant, given that no single ant possesses the global information of the needs of the colony?
  – behavioral flexibility of the workers: regardless of its castes, each ant is able to perform all assigned tasks.
  – response thresholds: each ant has a different response threshold toward each tasks.

Task Allocation

Response Thresholds

Fixed threshold model
Response Threshold Dynamics

- Workers with low response thresholds respond to lower levels of stimuli than workers with high response thresholds.
- Task completion reduces the intensity of stimuli.
- If workers with low thresholds perform their normal tasks, the task-associated stimuli never reach the thresholds of the high-threshold workers.
- But if, for any reason, the number of workers with low thresholds decreases or the intensity of the task-associated stimuli increases, high-threshold workers engage in the task.

Fixed Threshold Model

- Task $j$ stimuli intensity $s$ varies with time:
  \[ s_j(t+1) = s_j(t) + \delta - \varphi n_{act} \]
  where $\delta$ is the stimulus increase per unit time; $\varphi$ is the task performance efficiency of single ant; $n_{act}$ is the number of ants act on task $j$ at time $t$.
- Ant $i$ response probability to task stimulus $j$:
  \[ p_{ij}^{(inactive \rightarrow active)} = \frac{s_j^2 + \theta_{ij}^2}{s_j^2 + \theta_{ij}^2} \]
  where $\theta_{ij}$ is the response threshold of ant $i$ to task stimulus $j$. The lower the $\theta_{ij}$ is, the higher the $p_{ij}$ is.

Fixed Threshold Model - Continue

Variable Threshold Model

- Response function as before
- Introduce positive feedback
  - Learning: work on a task decreases threshold
    \[ \theta_i \leftarrow \theta_i - \frac{s_j^2}{\theta_{ij}} \] when $i$ performs the task
  - Forgetting: not working on a task increases threshold
    \[ \theta_i \leftarrow \theta_i + \varphi \] when $i$ not performing the task

Threshold Reinforcement

- Within individual workers, performing a given task decreases the corresponding threshold, and not performing the task increases the threshold.
- This threshold reinforcement process leads to the emergence of specialized workers, that is, workers that are more responsive to stimuli associated with particular task become better and better at that task.
- This threshold reinforcement also permits the adjustment, in response to changing internal ($\theta$) or external ($s$) conditions, of the numbers of workers engaged in different tasks.

Variable Threshold Model - Continue
Simplified Truck Painting Problem

- 3 possible truck colors: red, blue, green
- 3 booths originally loaded with red, blue and green paint.
- Painting each truck takes 2 minutes.
- The time for paint changeover is 1 minute.

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<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
</table>

Production line

Parameter

- Red booth: $\theta_{red}=1; \theta_{blue}=2; \theta_{green}=3$
- Blue booth: $\theta_{blue}=1; \theta_{red}=2; \theta_{green}=3$
- Green booth: $\theta_{green}=1; \theta_{red}=2; \theta_{blue}=3$
- $\xi=0.1 \phi=0.1$
- A booth accepts a new paint job when it is free and the probability of response to that paint job is higher than that of all other booths.

Fixed Threshold Model (t=1)

$$S_{red} = 1 \quad S_{blue} = 1 \quad S_{green} = 1$$

$$P_{red-red} = \frac{1}{1^2 + 1^2} = \frac{1}{2} \quad P_{blue-red} = \frac{1}{1^2 + 2^2} = \frac{1}{5} \quad P_{green-red} = \frac{1}{1^2 + 2^2} = \frac{1}{5}$$

Red Booth-paint red truck
Blue Booth-paint blue truck
Green Booth-paint green truck

Fixed Threshold Model (t=2)

$$S_{red} = 1 + 0 - 1 = 0 \quad S_{blue} = 1 + 1 - 1 = 1 \quad S_{green} = 1 + 1 - 1 = 1$$

$$P_{red-red} = \frac{0^2}{0^2 + 1^2} = 0 \quad P_{blue-red} = \frac{0^2}{0^2 + 2^2} = 0 \quad P_{green-red} = \frac{0^2}{0^2 + 2^2} = 0$$

Fixed Threshold Model (t=3)

$$S_{red} = 0 + 0 - 0 = 0 \quad S_{blue} = 1 + 0 - 0 = 1 \quad S_{green} = 1 + 1 - 0 = 2$$

$$P_{red-red} = \frac{1^2}{1^2 + 1^2} = \frac{1}{2} \quad P_{blue-red} = \frac{0^2}{1^2 + 2^2} = 0 \quad P_{green-red} = \frac{0^2}{1^2 + 2^2} = 0$$

Red Booth-change over to green paint
Blue Booth-paint blue truck
Green Booth-paint green truck

Fixed Threshold Model (t=4)

$$S_{red} = 0 + 1 - 0 = 1 \quad S_{blue} = 1 + 0 - 0 = 1 \quad S_{green} = 2 + 1 - 2 = 1$$

$$P_{red-red} = \frac{1^2}{1^2 + 1^2} = \frac{1}{2} \quad P_{blue-red} = \frac{1^2}{1^2 + 2^2} = \frac{1}{5} \quad P_{green-red} = \frac{1^2}{1^2 + 2^2} = \frac{1}{5}$$

Red Booth-paint green truck
Blue Booth-paint blue truck
Green Booth-paint green truck
<table>
<thead>
<tr>
<th>Fixed Threshold Model (t=5)</th>
<th>Variable Threshold Model (t=1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S_{red} = 1 + 0 - 0 - 1$</td>
<td>$S_{red} = 1$</td>
</tr>
<tr>
<td>$P_{red-truck} = \frac{1^2}{5+1} \frac{1}{2}$</td>
<td>$P_{red-truck} = \frac{1^2}{1+2} \frac{1}{5}$</td>
</tr>
<tr>
<td>$P_{blue-truck} = \frac{0^2+3^2}{4} \frac{1}{1+3}$</td>
<td>$P_{blue-truck} = \frac{0^2+3^2}{4} \frac{1}{1+3}$</td>
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<tr>
<td>$P_{green-truck} = \frac{2^2+3^2}{4} \frac{1}{1+3}$</td>
<td>$P_{green-truck} = \frac{2^2+3^2}{4} \frac{1}{1+3}$</td>
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<tr>
<td>Red Booth-paint green truck</td>
<td>Red Booth-paint red truck</td>
</tr>
<tr>
<td>Blue Booth-paint change over to green paint</td>
<td>Blue Booth-paint blue truck</td>
</tr>
<tr>
<td>Green Booth-paint green truck</td>
<td>Green Booth-paint green truck</td>
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<table>
<thead>
<tr>
<th>Variable Threshold Model (t=2)</th>
<th>Ant Parameters Optimization</th>
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<tbody>
<tr>
<td>$S_{red} = 1 + 0 - 0 - 0$</td>
<td>• What response thresholds $\theta$, $\varphi$, and $\xi$ the model should use to give the smallest time-span and paint waste?</td>
</tr>
<tr>
<td>$P_{red-truck} = 0 + 0.9^0$</td>
<td>• GA/PSO can be used to find these parameter values for improved performance.</td>
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<tr>
<td>$P_{blue-truck} = \frac{0^2+2.1^2}{0^2+2.1^2} = 0$</td>
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<tr>
<td>$P_{green-truck} = \frac{0^2+3.1^2}{0^2+3.1^2} = 0$</td>
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