Social Insect-Inspired Multi-Robot Coverage
(Extended Abstract)

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Categories and Subject Descriptors
H.4 [Information Systems Applications]: Miscellaneous

Keywords
bio-inspired, multi-robot systems, ant-inspired, bee-inspired, coverage

1. INTRODUCTION

Coordination is one of the most interesting and complicated research issues in distributed multi-robot systems (MRS), aiming to improve performance, energy consumption, robustness and reliability of a robotic system in accomplishing complex tasks such as coverage. Social insect-inspired coordination techniques achieve these goals by applying simple but effective heuristics from which elegant solutions emerge. Previous research investigated ant-inspired stigmergy (StiCo) and bee pheromone signalling (BeepCo) for multi-robot coverage [1, 2].

This paper tries to improve on previous approaches by introducing a hybrid ant-and-bee inspired approach, i.e., HybaCo. The proposed hybrid approach is evaluated in multiple scenarios using a high-level simulator and is compared to both StiCo and BeePCo. Experimental results from various scenarios identify strengths and weaknesses of the various algorithms and indicate that HybaCo effectively improves the area coverage uniformly.

2. BACKGROUND

For a detailed description of the StiCo and BeePCo algorithms we refer the reader to [1, 3]. The differences between the two techniques are described in Table 1.

<table>
<thead>
<tr>
<th>property</th>
<th>StiCo</th>
<th>BeePCo</th>
</tr>
</thead>
<tbody>
<tr>
<td>communication</td>
<td>Indirect</td>
<td>Direct</td>
</tr>
<tr>
<td>movement</td>
<td>Circular</td>
<td>Vector-based</td>
</tr>
<tr>
<td>speed to converge</td>
<td>Normal</td>
<td>Fast</td>
</tr>
</tbody>
</table>

Table 1: Differences between StiCo and BeePCo

3. HYBRID BEE-ANT COVERAGE

The most performance-limiting characteristic of the pheromone signalling approach (BeePCo) occurs when the robots lose their communication network by moving too far apart from each other. This prevents pheromone exchange and, as a result, robots stop moving. The biggest problem with the StiCo approach is the extended time to converge. In order to solve these two issues, HybaCo begins with BeePCo, but changes dynamically to StiCo when the communication network between the robots is lost. Pseudocode is shown in Algorithm 1.

Algorithm 1 Hyba-Co Algorithm

\begin{algorithm}
\begin{algorithmic}
\State time==0
\Loop
\If {Links to Neighbours Exist}
\State Apply BeePCo using bee pheromones
\Else
\State Apply StiCo using ant pheromones
\EndIf
\EndLoop
\end{algorithmic}
\end{algorithm}

4. EXPERIMENTAL EVALUATION

We evaluated all three algorithms (StiCo, BeePCo and HybaCo) using a custom-built simulator. The set of experiments presented in this section compare three important evaluation metrics: the area covered by the robots, the distribution of robots in their environment, and the time it takes to converge (or stabilise). The experiments were carried out with sets of 20, 30 and 40 robots, each robot having a sensing and communication radius of 25 cm. The robots’ environment (arena) size is 300 cm × 300 cm. We consider the following five algorithmic variations of StiCo and BeePCo in our comparisons: (1) StiCo: the robots use stigmergy; (2) BeePCo: the robots use bee-pheromone signalling; (3)
Figure 1: The percentage of area coverage using MRSs with 20, 30 and 40 robots: StiCo versus BeePCo

**BeePCo with rotation:** BeePCo extended with a rotational move; (4) HybaCo: the robots use the hybrid algorithm; and (5) MaxCo: the optimal case, where the robots’ transmission range does not intersect with each other. This can also be referred to as potential coverage.

All results are averaged over 30 independent runs to assure statistical significance. We only show a selection of experiments due to page constraints. In Figure 1, the StiCo and BeePCo algorithms are compared against each other with respect to area coverage using 20, 30 and 40 robots. For both StiCo and BeePCo, we observe that the percentage of area covered increases as the number of robots increases, as expected. BeePCo provides considerably higher area coverage in comparison to StiCo.

Figures 2 and 3 illustrate the experimental results on a MRS with 40 robots and compares the performance of the StiCo, BeePCo, BeePCo with rotation and HybaCo approaches against each other in terms of the percentage of area coverage (due to space limitations, we do not show the results of the comparable experiments for 20 and 30 robots, but results are similar). These results illustrate that HybaCo improves performance and achieves better area coverage than the StiCo and BeePCo with rotation approaches. The distribution of the robots is illustrated using heatmaps (Figure 3). These plots show that HybaCo and BeePCo with rotation improve robot distribution and encourages robots to spread around the arena more, as opposed to the StiCo and BeePCo approaches. Although BeePCo with rotation performs worse than HybaCo, the improvement over the StiCo and BeePCo approaches is still significant.

5. CONCLUSIONS

We have shown the performance of StiCo, BeePCo and HybaCo in regard to a number of criteria, including area coverage, uniformity of distribution and speed of convergence, and we also developed a hybrid bee-and-ant inspired approach that merges the strengths of StiCo and BeePCo into one algorithm. The advantages and disadvantages of these two techniques have been highlighted. In the second set of experimental results, we evaluated the effectiveness of the proposed hybrid bee-and-ant inspired approach, i.e., HybaCo and reported our observations.

6. REFERENCES

