Swarm compactness maintenance using only local communication
Modelling the $\alpha$-algorithm at different scales

- Sub-microscopic scale: near real hardware, implementation similar to the one on real hardware.
- Microscopic scale: at agent scale, may be spatial or stochastic (non-spatial)
- Macroscopic: the whole swarm modelled in a mean sense by a set of equations (Markov chain)
The sub-microscopic model

- If number of connection drops below $\alpha$ make a U-turn.
- If a connection is regained return to Forward state and make a random turn.
- Else return in Forward state anyway.
Results for the sub-microscopic model: a swarm of 40 robots

Mean of results for 40 robots, $\alpha = 5, 10$ and $15$
Results for the sub-microscopic model: the importance of time parameters

Mean of results for 40 robots, $\alpha = 5, 10$ and $15$
The macroscopic model

- Model the swarm as a PFSM, saying a Markov chain.
- Estimate probabilities based on results of sub-microscopic model.
- Find equilibrium state using simple linear algebra.
Searching for the equilibrium state

\[ \vec{S}_{n+1} = \vec{S}_n + P\vec{S}_n = (I + P)\vec{S}_n \]

search for \( P\vec{S}_n = \vec{0} \)

- Search of the kernel of a transition matrix.
- Possible that kernel is of dimension greater than 1.
- Run many steps or reduce the system to the states that are reachable (not implemented).
Estimating transition probabilities

\[ p = \frac{1}{T} \]

- Based on the formula of return period.
- Datas are obtained for all replicates, then the mean of all replicates is taken.
- The procedure is to count the number of occurrence of the event related to a probability and divide it by the number of steps spent in the state before.
- It is an oversimplification not taking into account the fact that many type of event can lead to quit a state. A more detailed return period analysis with event interdependence should have been performed.
Results for the macroscopic model

Mean of mean of results and equilibrium state for 20 robots, $\alpha = 5$ and 10 and 40 robots, $\alpha = 15$
A possible improvement for probabilities evaluations

For all replicates:

\[
\bar{S} = \hat{S} \quad \hat{p} = \hat{p} \quad \hat{P} \hat{S} = \tilde{0} \quad |\text{swarm}(\hat{S})| = |\text{swarm}(\bar{S})|
\]

with:

\(\bar{S}\), the estimated equilibrium state of replicate
\(\hat{S}\), the true equilibrium state
\(\hat{p}\), the estimated transition probabilities of replicate
\(\hat{p}\), the true transition probabilities
\(\hat{P}\), the transition matrice based on true transition probabilities

- Functional equations with non-linear constraints on the parameters, may be solved in the last square sense with advanced methods.
- Possible to replace the first constraints on the parameter by a functional dependence between them if \(\text{Dim}(\text{Ker}(P)) = 1\).
- Running time linear with respect to the number of replicates with correct implementation.
- Possible to select weights to give more importance to match the equilibrium state with the mean states or the probabilities together.
- Sadly not implemented due to time constraints.
The microscopic model

- Implemented spatially rather than stochastically.
- Still buggy, not corrected due to time constraints.
- Important lesson: modelling is not implementing and a bug can change results, this is why submicroscopic modelling is interesting because implementation is really near real hardware implementation.
Conclusions

• Modelling can be a complex task, simplifications are useful but risk to bring errors. Understand how to pay attention for such errors is needed!

• Some simple way to match macroscopic models with smaller range models have been explored, some more advanced were proposed. (importance may depend of the goals).
Any questions?

Thanks for your attention
REFERENCES