TEK9010 - Exam prep summary

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9: Swarm Robotics 1

What is swarm robotics?

Quick answer: swarm intelligence applied to robotics.

There is no explicit definition of a *swarm* in literature. A swarm is defined via its behavior.

The *size of a swarm* is defined by what it is not: "not as large as to be dealt with statistical averages" and "not as small as to be dealt with as a few-body problem". The size of a swarm N is

$$10^2 < N << 10^2 3,$$

not Avagadro-large.

Swarm robotics is "the study of how a large number of relatively simple physically embodied agents can be designed such that a desired collective behavior emerges from local interactions among agents and between agents and the environment", according to Dorigo and Sahin. But! A swarm is not necessarily

There are some key features. The fact that local interactions between agents and the environment should be possible requires robots to have local sensing and probably also communication capabilities. In fact, (local) communication is considered a key feature of swarms.

Collaboration is required to go beyond a mere paralllisation in swarm a swarm system. We want to go beyond the performance of simple parallelisation. Think of some clearning task with each robot cleaning a small assigned area.

Swarm performance.

Some keywords are *contention* or *inference* and (lack of) *coherency*, given by parameters α and β, repectively. The robots need to share limited resources and communicate. This is difficult.

In the contexst of swarm robotics we can interpret contention as interference between robots due to shared resouces, such as an entrance to a base station or generally space. Collision avoidance is a waiting loop because the shared resource *space* is currently not available. This can be compared to an airplane flying in a holding pattern because the resource "runway" is currently in use and should certainly not be shared. Incoherency, in turn, can be interpreted as inconsistencies or overhead due to limited communication of imformation or due to imperfect synchrony.

The univeral scalability law is important,

$$R(N) = \frac{N}{1 + \alpha(N-1) + \beta N(N-1)}.$$

Its inverntor, Gunther, identifies four qualitatively different situations,

1. If contention and lack of coherency are negligible, then we get "equal bang for the buck" and have a linear speedup ($\alpha = 0$, $\beta = 0$),
2. If there is a cost for sharing resources in the form of contention, then we have a sublinear speedup ($\alpha > 0$, $\beta = 0$),
3. If ther is an increased negative influence due to contention, then the speedup clearly levels off ($\alpha >> 0$, $\beta = 0$).
4. If in additon there is also an increased influence of incoherence, then there exists a peak speed up and for bigger system sizes the speedup decreases ($\alpha >> 0$, $\beta > 0$).

One can identify some "regions" of performance; super-linear, sub-linear, optimal and inference. As more agents are added, performance starts to increase (sub-/super-)linearly, then we get to an optimum after a while. After that comes the inference region.

In parallel computing, superlinear speedups can occur due to some interplay between problem size per computing unit and available memory. For example, if the problem can be divied into pieces that fit completely into a CPUs cache, then one can observe a considerable speedup. In swarm robotics, superlinear performance increases occur due to qualitatively different collaboration modes that are accessible with increasing swarm size as seen in bucket brigades.

It is possible for a system-wide deadlock to occur in a swarm robotics system. For instance with a very high swarm denisty, such that all robots permanently try to avoid collisons resulting in zero performance.

Modelling swarms as a series of mappings.

When are rate equations appropriate?
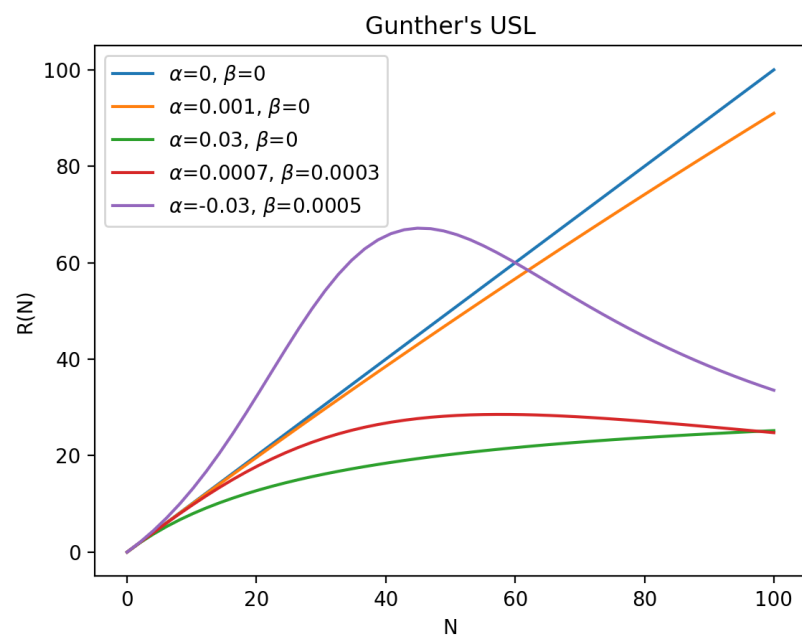
The Langevin equation.

The Focker-Planck equation.

Figure 1: Gunther's Universal law of Computational Scalability