

From Swarm Intelligence to Swarm Robotics

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Goal

- Help start a discussion to clarify some concepts related to swarm robotics
- Clarification is useful because there is some confusion in what it means doing research related to swarms
- It appears that the term 'swarm' is used somewhat indiscriminately

Evolution of swarm terminology

- Swarm
- Swarming
- Swarm intelligence
- Swarm optimization
- Swarm robotics

A starting point for discussion

Why 'swarm' ?

- Not just a buzz word for a *cooperating group*
- Distinct features:
 - 'Intermediate' number of units: $\sim 10^2$ - $10^{<<23}$
 - Simple and quasi-identical units
 - Decentralized control
 - Lack of synchronicity

Promised advantages

- **Simple** units could be
 - Mass produced
 - Interchanged
 - Disposable
- **Redundancy** could result in
 - Reliability
 - Adaptation
- Massive computation (maybe)

Insect societies

- Match the characteristic features of swarms (not surprisingly)
- **Biologists** tried to model insect social behavior -- while **roboticists** tried to make swarms do prescribed tasks
 - **Biologists** contributed, e.g., with the mechanism of 'stigmergy' (= communication by way of the environment)

Swarm Optimization

- Significant progress
- Ant Colony Algorithm (Dorigo)
- Particle Swarm Optimization (Kennedy-Eberhart)
- Stochastic, asynchronous, decentralized

Roboticians and Biologists

- Roboticians

- Mainly interest in Pattern **Synthesis**
 - Self-organization
 - Self-reproduction

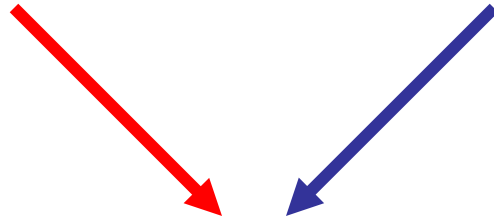
- Biologists

- Mainly interested in Pattern **Analysis**
 - Recognizing best pattern
 - Optimizing path

Toward intelligent behavior

- Pattern **Synthesis**

- Pattern **Analysis**



? Intelligence ?

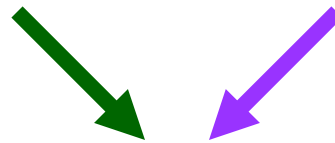
Why 'Swarm Intelligence'?

- Well known difficulties with
- ~~Most characteristics of~~ 'intelligence' can be found in some 'non-intelligent' system
- Elusive concept

Let's look at characteristics of 'intelligence' relevant to **Robotics**

Two main characteristics of intelligent behavior

- 'Ordered' outcome
- example:
 - Machine producing a mechanical piece for a car
 - Outcome is 'ordered' but it is predictable
- 'Unpredictable' outcome
- example:
 - Rolling of dice
 - Outcome is 'unpredictable' but does not produce 'order'



Intelligent

Ad hoc definitions

- Machine
 - Capable of processing **matter/energy**
- Automaton
 - Capable of processing **information**
- Robot
 - Capable of processing both

NOTE: these definitions apply to groups as well as single entities

Groups of machines can be robots since they can encode information while processing matter/energy

'Intelligent' robot

- Robot capable of forming 'ordered' material patterns

Note: 'unpredictably'

- **Analysis** of pattern can be done by automata (the operation deals purely with representations)
- **Synthesis** of material patterns cannot be done by pure automata – robots are needed.

Intelligent Swarm = Group of 'machines' capable of forming 'ordered' material patterns 'unpredictably'

Intelligent Swarm= Group of
'machines' capable of forming
'ordered' material patterns
'unpredictably

- Producing order = computation process

Intelligent Swarm = Group of
machines capable of
'unpredictable' material
computation

Unpredictable ?

- The system making the prediction must be able to outrun the system it is trying to predict
- If the system is capable of **universal** computation it cannot be outrun
- Intelligent Swarm = Group of machines capable of **universal material computation**

Swarm Intelligence

Intelligent Swarm = Group of machines
capable of **universal material**
computation

Does such thing exist?

Probably very common

- Made now very clear by the recent formulation (by S.Wolfram) of the
- Principle of computational equivalence
 - All processes not obviously simple are capable of universal computation
- From which follows computational irreducibility
 - For all processes not obviously simple there is no way to shortcut their process of evolution

Swarm Robotics

- Intermediate number of units (10^2 - $10^{<<23}$)
- Simple (almost) identical units
- (generally) not centralized and not synchronized ???
- (mostly) local interactions ??

- **The actual engineering of systems ultimately capable of swarm intelligence**

End

Thank you for your attention