On the need of Hybrid Intelligent Systems in Modular and Multi Robotics

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- Multi-robot systems
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Introduction

- New task features
  - Highly dynamic unstructured environments and
  - The tasks to be performed are seldom carried out in the same exact way,
- Examples
  - Shipyards
  - Plants for constructing unique large structures

Introduction

- Desired properties of robotic systems
  - Modularity
  - Scalability
  - Fault tolerance
  - Ease of reconfiguration
  - Adaptation
  - Low fabrication and maintenance costs

Introduction

- Multi-robot and modular robotic systems
  - Are naturally modular
  - Scalability can be easily achieved adding
  - Fault tolerance is achieved through distributed control and task/role distribution
  - Reconfiguration is obtained through
    - Individual robot motion
    - Relative positioning of modules

Introduction

- Multi-robot and modular robotic systems (cont.)
  - Can easily adapt to changes in
    - Environment configuration
    - Task definition
  - Fabrication and maintenance costs are linear in the number of components.

Introduction

- Hybrid intelligent systems:
  - Composition of heterogeneous computational tools
    - Knowledge representation: Fuzzy systems, bayesian reasoning, neurla networks
    - Optimization: Genetic Algorithms, Evolutionary Strategies, Artificial Inmune Systems, Simulated Annealing
    - Filtering: data reduction, image and signal processing

Introduction

- Composition/decomposition
  - Connected continuous robot
    - Homogeneous:
  - Distributed multi robot system
    - Heterogeneous: task decomposition
  - Distributed cooperative robot
    - Independent robot units
    - They do not require others to fulfill the task
    - Cooperation --> scale, resource optimization

Modular robots

- Robotic structures that are made up of multiple, generally identical, modules
- Cellular automata and social insect theories
- Behavior emergence and holistic principles
- Autonomous (without human intervention)

Modular robots

- Interesting behaviors
  - autonomously self-organize and change their shape in order to adapt to different tasks or classes of terrain
  - potential for self repair: it is possible to eliminate the damaged module and substitute it using another one

Modular robots

- State of the art
  - have achieved their objectives only in very controlled laboratory environments
  - control systems within the modules are created ad hoc for the task to be carried out

- Potential field for Hybrid Intelligent Systems
  - Autonomous self reconfiguration through state estimation (NNs) and optimal transformation computation (EAs).
  - Evolutionary design of system modules
  - Sensing for
    - Estimation of self configurations
    - Goal attainment

Multi robot systems

- **robot swarms** : groups of robots that collaborate to achieve an objective
  - rescue tasks
  - material handling in flexible fabrication cells
  - the RoboCup
- Biological foundations

Multi robot systems

- State of the art
  - Ad hoc individual logic programming
  - Tailored experimentation for proof of concept (swarmbots)
  - Need of central controller:
    - Perception
    - State estimation
    - Control commands

Multi robot systems

- Potential for hybrid intelligent system
  - Enhance internal individual dynamics with approximate reasoning.
  - Enhance communication between individuals
    - Direct: via signal processing
    - Stigmergy: via intelligent optmization swarm design
  - Sensor information fusion
    - Map building
    - Localization

Multi robot systems

- Potential for hybrid intelligent system
  - Decentralized control strategies
    - Incomplete, temporally inconsistent information
    - Evolutionary approaches

Concluding remarks

- General application potential for HIS
  - Sensing
    - Self-state estimation
    - Distributed Environment Sensing
    - Sensor fusion
  - Control strategies
    - Fully autonomous adaptation
    - Optimal planning