DESENVOLVIMENTO DE SISTEMAS INTELIGENTES PARA ESCALONAMENTO

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Motivation

- Current financial and economic challenges require and promote organizations to adopt agile techniques for planning, scheduling, and decision making
- **Scheduling** is a critical issue in planning operations and is crucial for improving production performance
- **Decisor** needs to make the right decision **when** and **where** it is important to the business
- Optimization in dynamic environments has attracted a growing interest due to its pratical relevance
- A challenge is emerging in the **design of scheduling support systems** for manufacturing environments where **dynamic adaptation** and **optimization** become increasingly important

Research Projects

- **MASDScheGATS** - Sistema Multi-Agente para Escalonamento Distribuído da Produção com Algoritmos Genéticos e Pesquisa Tabu (POCTI/EME/61229/2004)

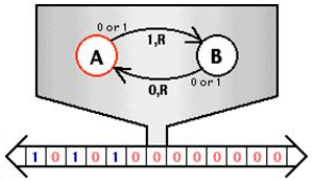
- **AutoDynAgents** - Agentes Autónomos com Capacidade de Auto-gestão para Apoio ao Escalonamento Dinâmico em Sistemas Cooperativos de Fabrico (PTDC/EME-GIN/66848/2006)

- **ADSyS** - Sistema de Apoio à Decisão Adaptativo e Interactivo para Escalonamento com Metacognição e Modelação da Experiência do Utilizador (PTDC/EME-GIN/109956/2009)

Intelligent Systems: Definitions and Concepts

- An intelligent system should:
  - Support decision makers by gathering and analyzing evidence
  - Identify and diagnosing problems
  - Recommend/propose possible actions
  - Evaluate the proposed actions
- Consider some properties:
  - Learning
  - Autonomy
  - User friendly interaction and user modeling
  - Adaptation
- Use of artificial intelligence (AI) techniques

Artificial Intelligence: Contributions



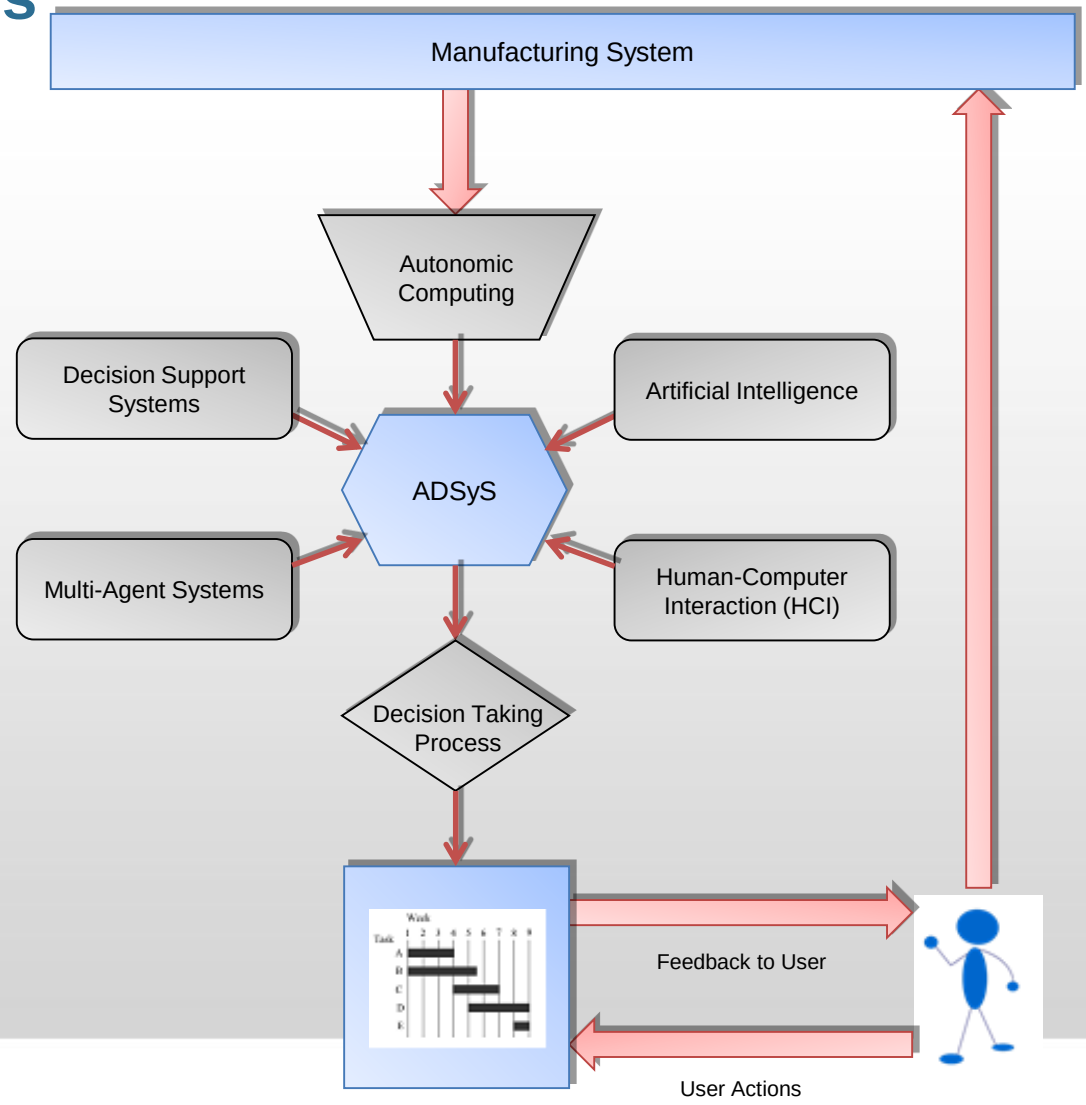
- Alan Turing (1912-1954)
  - 1936: The Turing machine, computability, universal machine
  - 1939-40: The Bombe, machine for Enigma decryption
  - 1950: The Turing Test for machine intelligence

- John McCarthy (1927-2011)
  - founder of the discipline of artificial intelligence
  - proposed the term "artificial intelligence" (AI)
  - 1st international conference on artificial intelligence (1956)
  - developed the Lisp programming language family
  - influenced the design of the ALGOL programming language

Prototype of Intelligent and Adaptive System for Scheduling

- Perform scheduling in highly **dynamic environments** where there is incomplete information and changes often occur
- Modify previously formed schedules considering recent dynamic information, minimizing the disruption of earlier schedules and aiming for the most effective possible use of resources and achievement of goals
- Provide flexibility to **react robustly** to any disruption in an efficient manner
- Requiring **minimal manual intervention**
- **Increase productivity** and **effectiveness** while **minimizing complexity** for users

Intelligent and Adaptive System for scheduling: Paradigms



Autonomic Computing

- Self–managed systems have the **ability to manage themselves** and to **dynamically adapt to change** in accordance with evolving or dynamic business policies and objectives, allowing the addition and removal of resources/tasks with-out service disruption, and with **minimum human intervention**.
- AC concept is based on four **self-* properties**, in which research efforts may be categorized:
  - **Self-Configuration** – capacity of a new component autonomously insert in the system
  - **Self-Optimization** – ability to autonomously improve system's performance be able to reach certain objectives
  - **Self-Healing** – ability to autonomously recover from failures in the system
  - **Self-Protection** – capacity of the system to protect itself against malicious attacks

Human-Computer Interaction

- Human-Computer Interaction (HCI)
  - arises as a research area that studies the interactions and the relationships between humans and computers
  - a multidisciplinary and an evolving field covering diverse research areas
    - **User Interface development**
    - **Usability**
    - **User Modelling**

Multi-Agent Systems

- a computerized system composed of multiple interacting intelligent agents within an environment.
- can be used to solve problems that are difficult or impossible for an individual agent or a monolithic system to solve.
- agents could cooperate or compete for the resources

Cooperation in Multi-Agent systems

- In a MAS there is more than one agent interacting with each other and there are constraints such that agents may not, at any given time, know everything about the environment that other agents know.

- The emergence of cooperation is often studied in the context of social dilemmas, in which selfish individuals must decide between a socially reciprocal cooperative behavior and a self-interested behavior of defection to pursue their own short-term benefits.

- Solving the problem of how cooperation emerges among self-interested entities is a challenging issue.

Biological Inspired Optimization techniques

- Biological processes have been a source of inspiration for the sciences and engineering:
  - **Evolutionary computing** is based on the Darwinian notions of survival of the fittest and evolution
  - **Particle Swarm Optimization** is based on the theory of swarming insects or flocking birds
  - **Ant Colony Optimization** algorithm takes inspiration from the foraging behavior of some ant species
  - **Bee based Optimization techniques** are inspired by the intelligent foraging behavior of honey bees
    - In a beehive, the group has some specific tasks performed by specialized individuals.
    - Natural bees are known for the adaptation to changes in the environment in a collective intelligent way.

Machine Learning

- **Machine learning**, a branch of **artificial intelligence** research area, that concerns with the construction and study of systems that can **learn** from data, based on experience or even by observation:
  - Case Based Reasoning
  - Neural Networks
  - Support Vector Machines
  - Bayesian networks
  - ….
  - Clustering

User Modelling

- User modeling and user adaptive interaction has become a central applied issue to understand users as they interact with technology
- The system users will be classified in one of three levels:
  - beginner (level 1),
  - intermediate (level 2)
  - advanced (level 3).
- Each level has different needs, and if the interface is designed to meet those needs, each group will be more satisfied than if the design is done only targeting one level (or all of them).
- Permits to classify system users according to the actions performed through the system. User interface will adapt itself to the user profile and offers helps and recommends actions according to user level;

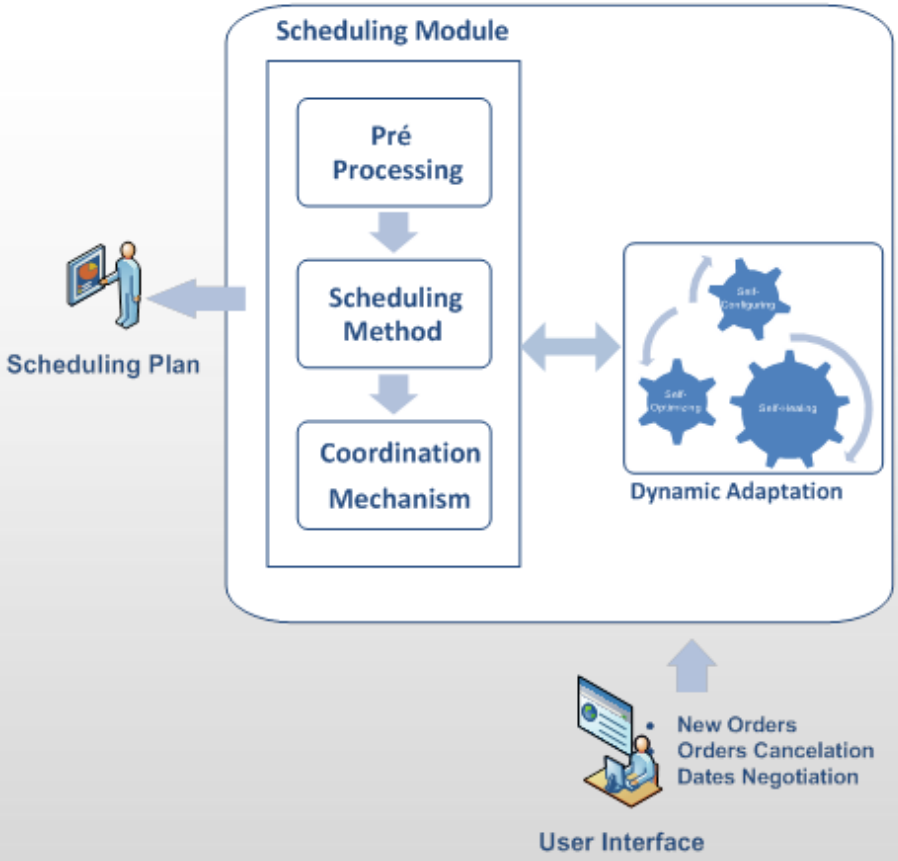
Prototype of Intelligent and adaptive system

- Manufacturing environment is modelled through an autonomic multi-agent system composed by four classes of agents.
- The system must be able to:
  - Deal with dynamism (new jobs arriving, cancelled jobs, changing jobs attributes, etc.);
  - Change/adapt the parameters of the basic algorithm according to the current situation;
  - Switch from one Meta-Heuristic algorithm to another;
  - Each Resource Agent find optimal or near optimal local solutions through a Meta-heuristic;
  - Resource Agents cooperate with each other.

System Architecture

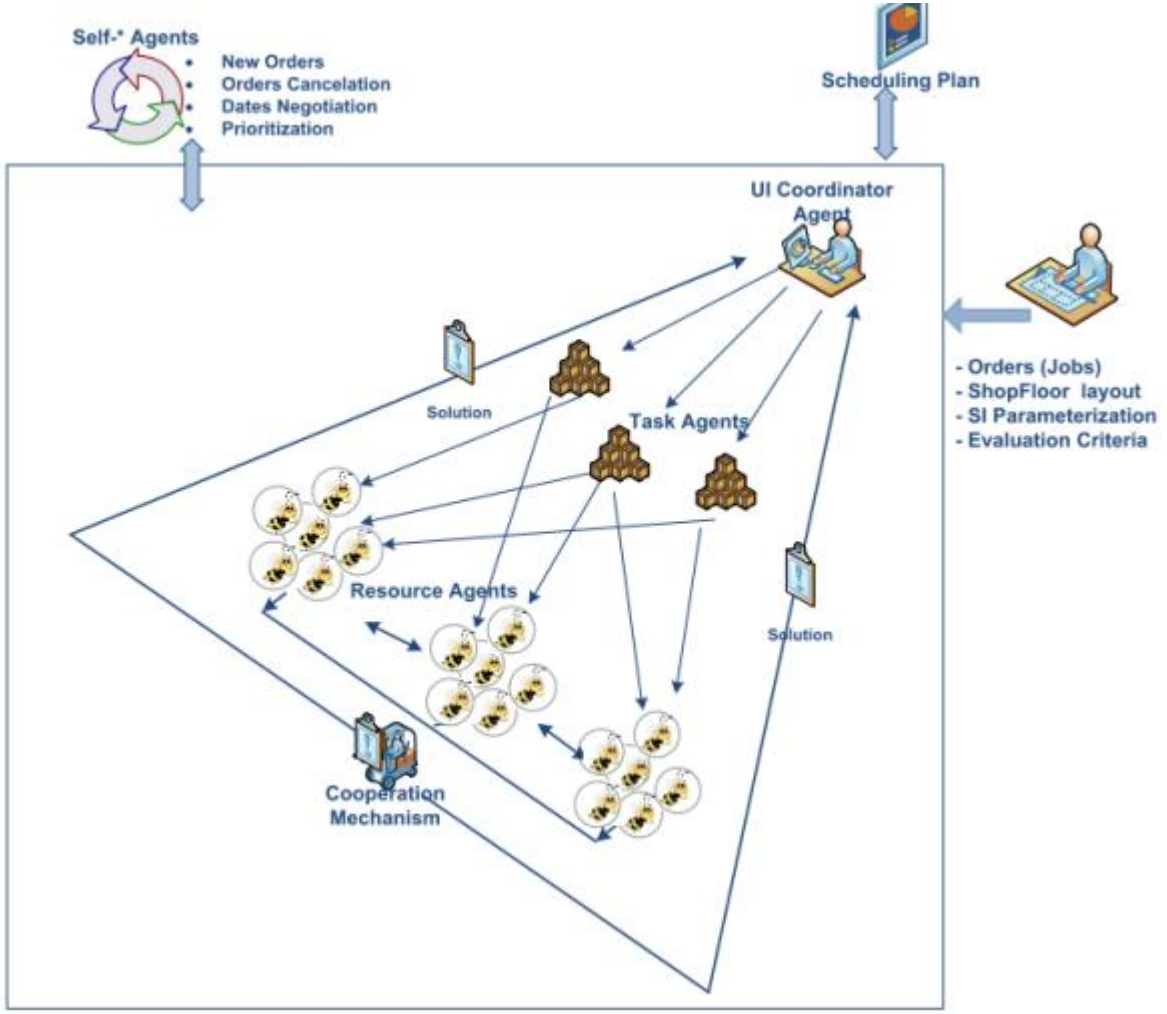
- **Scheduling Module** - is the scheduler itself, constructs a scheduling solution to the problem instances throughout a Meta-heuristic technique.

- **User Interface Module** - allows interactivity between the user and the scheduling module by permitting the input of problem data information, MH definition and parameterization; results visualization and summary reports in Gantt charts; and gives users the possibility of interaction with Gantt charts



System Prototype Model

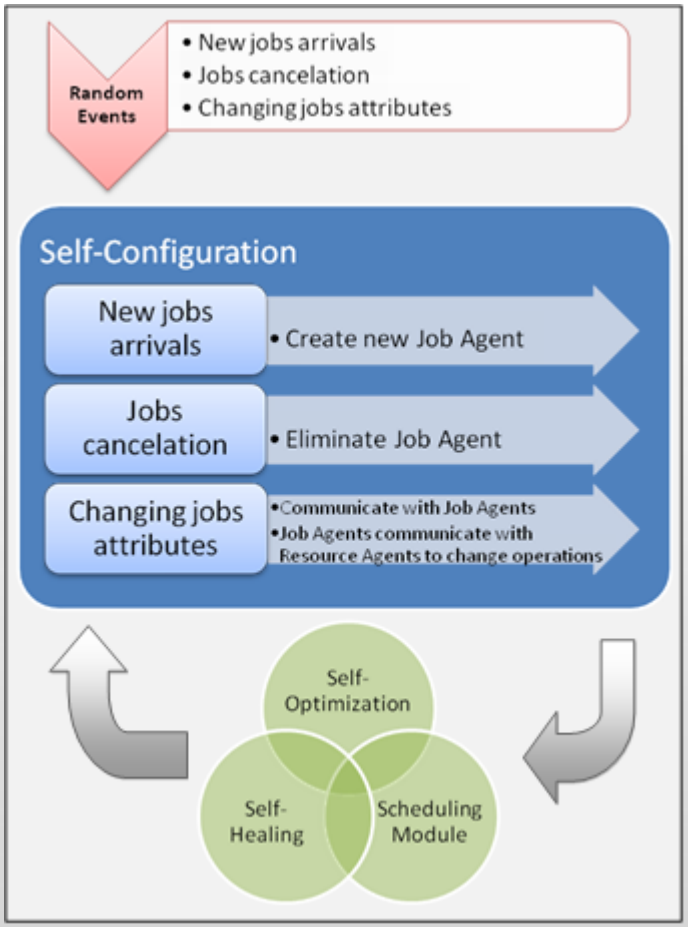
- **Multi-Agent System:**
  - **UI Agent**
  - **Task Agents**
  - **Resource Agents**
- **Self-* Agents:**
  - **Self-Configuration**
  - **Self-Optimization**
  - **Self-Healing**



Self-Organization behaviour

- able to monitor the system and detect the changes occurred in the environment. The system is prepared to automatically handle with dynamism by adapting the current solutions to external perturbations.
  - Partial and total events

- Self-Configuration workflow is cyclic, since it is continuously monitoring the system.



Cooperation Mechanism for Distributed Resource Scheduling Self-Organized System

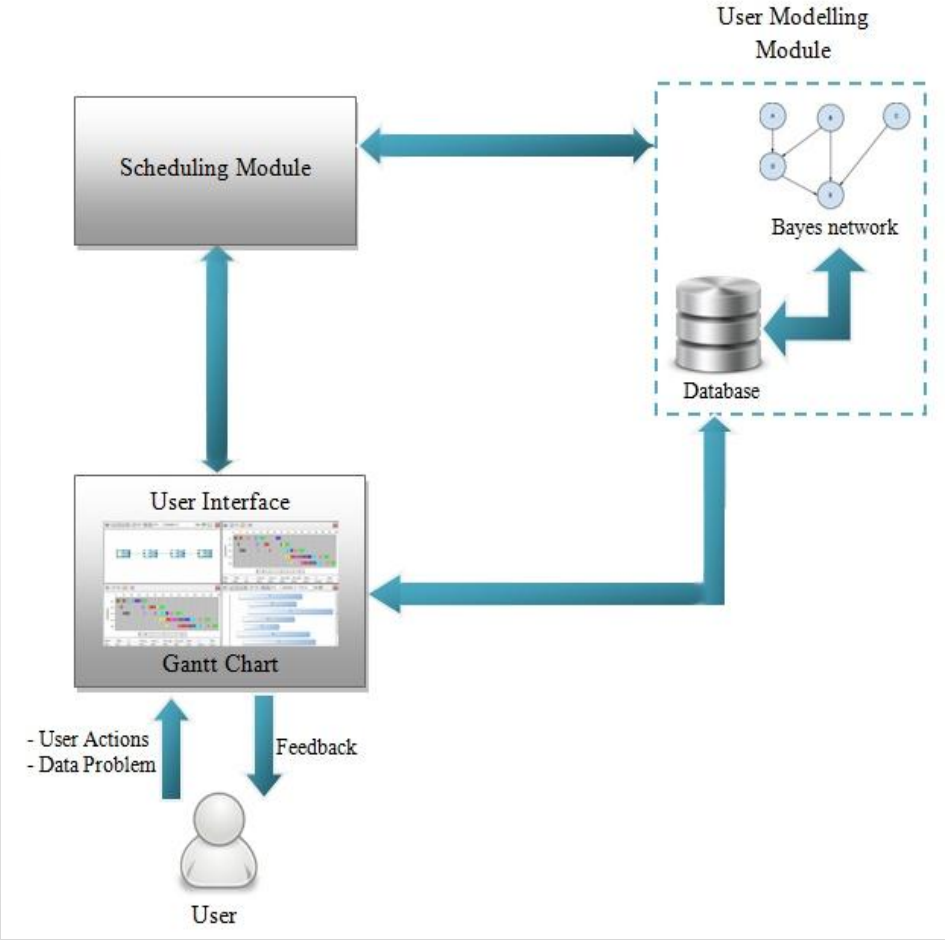
- Based on a Resource Oriented Decomposition Approach where the scheduling problem is decomposed into a series of Single Machine Scheduling Problems.
- Resource Agents (which have a BIO method associated) obtain local solutions that will be integrated in a global solution
- and later cooperate in order to overcome inter-agent constraints and achieve a better global schedule.
- This considers a specific kind of social interaction, known as cooperative problem solving, where the group of agents work together to achieve a good solution for the problem.
- Multiple self-interested agents can reach agreement over the exchange of operations on cooperative resources.

Cooperation mechanism for distributed scheduling

- Used when a global solution has been attained by the scheduling module
- Agents must collaborate to improve their local solutions and the global schedule.
- Proposed cooperation mechanism is able to analyze the scheduling plan generated by the Resource Agents and refine it by idle times reducing taking advantage from cooperative and the self-organized behavior of BIO techniques.
- Minimizes the machines' (resources) idle times by swapping operations, keeping all restrictions imposed by the problem
  - Makespan
  - Resource occupation

User Modeling Module

- permits to classify system users according to the actions performed through the system. User interface will adapt itself to the user profile and offers helps and recommends actions according to user level;



Conclusions

- A proposal of a simple architecture for a self-organized decision making system able to support dynamic and distributed scheduling in manufacturing systems.
- Take advantage from the potentialities of hybridization of different paradigms
- Uses multiple self-interested agents that collaborate to improve the global schedule
  - the system is capable of autonomously detect changes and also integrate them,
  - adapting the plans in real time, according to occurred perturbations in the scheduling plans.
  - resource agents receive the information and are prepared to integrate the changes, by adapting each single-machine plan, and later communicate to the interface.
  - Associated to the system adaptation the number and state of resources are adapted to task arrivals/cancellations that have associated a creation/elimination of a new Task Agent.
- The interface adapts to users system level of expertize, to provide the adequate helps and recommendations to accomplish the scheduling system operations.