**Single agent:**

* **Relaxed problem** (remove constraints for all cases – compute heuristics)
  + Add edge
  + Reduce number of nodes
* **Ignore precondition**
* Ignore precondition and non-goal literal heuristics (**remove negative effects**)
* **Additive heuristics and max heuristics**
* **Partial-order planning** (POP): A planning technique producing partially ordered plans, ignoring the ordering of independent actions + use of threads of independent goals
* **Hierarchical planning** (decompose problem into a tree structure)

**Multi agents: Re-planning**

* **Action monitoring**: when an action is about to be performed, check that all preconditions of the action still hold (e.g. by sensing).
* **Plan monitoring:** when an action is about to be performed, check that the remaining plan will still succeed (nothing has destroyed the possibility of carrying out the remaining actions of the plan).
* **Goal monitoring:** when an action is about to be performed, check to see if there is a better set of goals that the agent might try to achieve. This requires some degree of intentionality, which will be discussed further in the following.
* **repair** the plan by planning how to get back to a state from which the original plan can be continued (using partial order planning)
* Make agents **cooperate, coordinate, and negotiate** with each other
* **Multibody vs multi-agent**
* **The martha project** provide an efficient multi-agent re-planning algorithm can be used.

|  |
| --- |
| 1. A centralized planner distributes transportation jobs to the  individual dock-worker robots. 2. The robots then plan and schedule their own transportation jobs  individually, not taking the other robots into account. 3. Each computed individual plan is publicly broadcasted. 4. In case of resource conflicts, the robot causing it will be asked to replan    1. Resolving resource conflicts: Robot r broadcasts its computed plan. If robot s needs one of r’s scheduled resources, s will ask r to replan.    2. Problem: r might not be able to replan, e.g. in case of a deadlock loop.    3. In this case, the robot r will perform centralised planning (multibody   planning) for the subset of robots involved in the conflict/deadlock loop. |
| General approach underlying Martha project:   1. First “pretend” the individual agents’ problems are completely  decoupled (a relaxed problem). 2. Solve the individual problems separately. 3. Fix up the interactions (conflicts) by communication and coordination |

* **Task sharing**: How to share tasks between agents through
  + communication and coordination.
  + Common methods for task sharing: • Negotiation. • Bidding. • Voting.
  + Conventions and social laws.
* **BDI architecture (most used by DTU students)**
* **Multi-agent approach**
  + Speech acts (use of **ACL language**)
  + **Benevolent agents** 
    - **cooperative distributed problem solving (CDPS)**
    - **Task sharing** using decomposition and allocation
      * **Task allocation protocol (CNET protocol) – can be combined with ACL**
      * 1. Problem recognition. What is the problem to be solved?
      * 2. Task announcement. Agent 1: “Can anybody help me with this?”
      * 3.Bidding for the task. Agent 2: “I can do it in time t2.” Agent 3: “I can do it in time t3.”
      * 4. Awarding the task. Agent 1: “Agent 2 wins the bid”.
      * 5. Expediting task. Agent 2 carries out the contracted task.
    - **Result sharing** either proactive or reactive
      * Blackboard architecture (shared data structure)
      * Metaphor: turn based contribution to the blackboard
      * **Coordination of result sharing**
        + **Social laws**
  + self interested agents
  + **partial global planning**
    1. Local plan formation
    2. Partial global plan construction and modification
    3. Acting

**Plan**

**Partial order planning**

**Implements Heuristics to reach sub-goals**

**Multi-agent system**

**Monitoring**

**Handle Agent communication**

**Plan merging**