UNIVERSITÀ
DEGLI STUDI
DI PADOVA

ARCHITECTURES FOR AUTONOMOUS ROBOTS

Prof. Emanuele Menegatti

Intelligent Robotics Course

DIPARTIMENTO
DI INGEGNERIA
DELL'INFORMAZIONE

INTELLIGENT AUTONOMOUS SYSTEMS LAB

HYBRID ARCHITECTURES /1

- Neither completely deliberative nor completely reactive approaches are suitable for building agents

  - researchers concluded using *hybrid* systems, which attempt to combine hierarchical and reactive approaches

- An obvious approach is to build agents out of two (or more) subsystems:

  - a *deliberative* one, containing a symbolic world model, which develops plans and makes decisions in the way proposed by symbolic AI

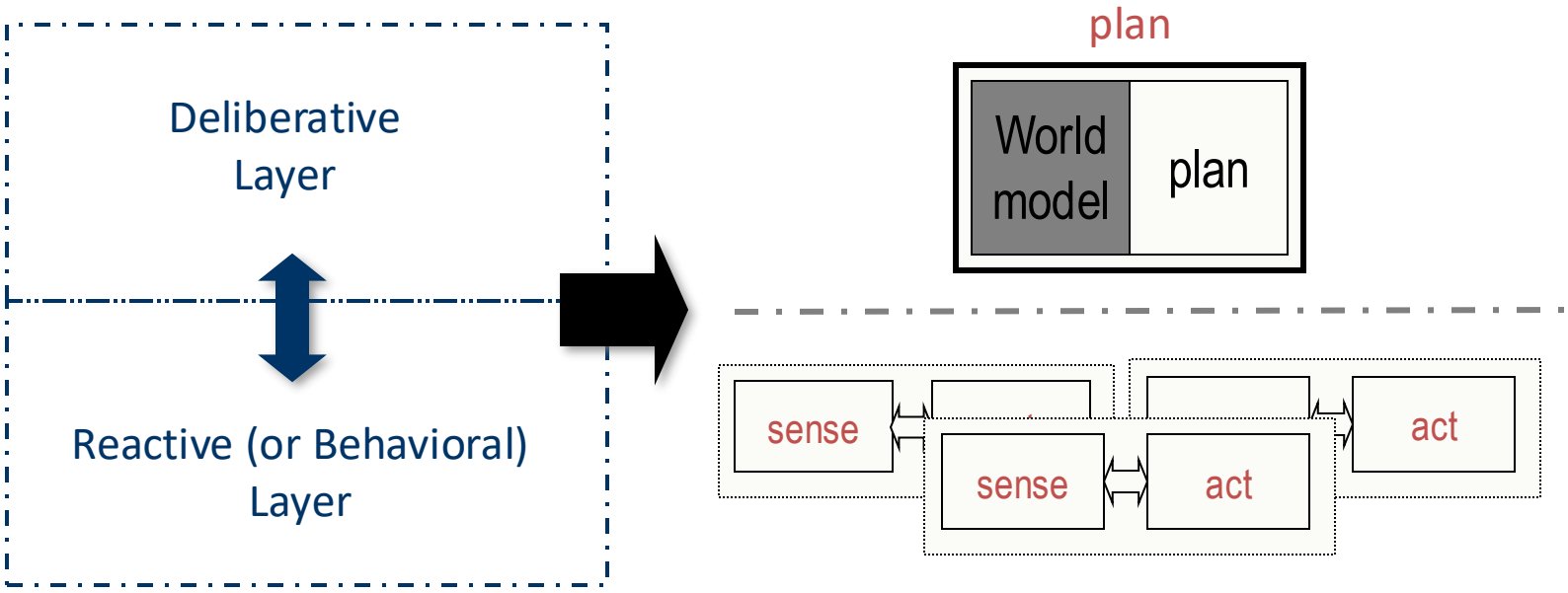
  - a *reactive* one, which is capable of reacting to events without complex reasoning

- The combination of reactive and proactive behaviours leads to a class of architectures in which the various subsystems are arranged into a hierarchy of interacting *layers*

Hybrid Architectures aims to mix the two approaches in order to get an overall better performance

- The critical point is the choice of the degree of balancing:
  - How much is left to reactivity and how much is left to deliberation?
- Is it possible to move the equilibrium point between the two extremes while the system is performing? And if so, how?

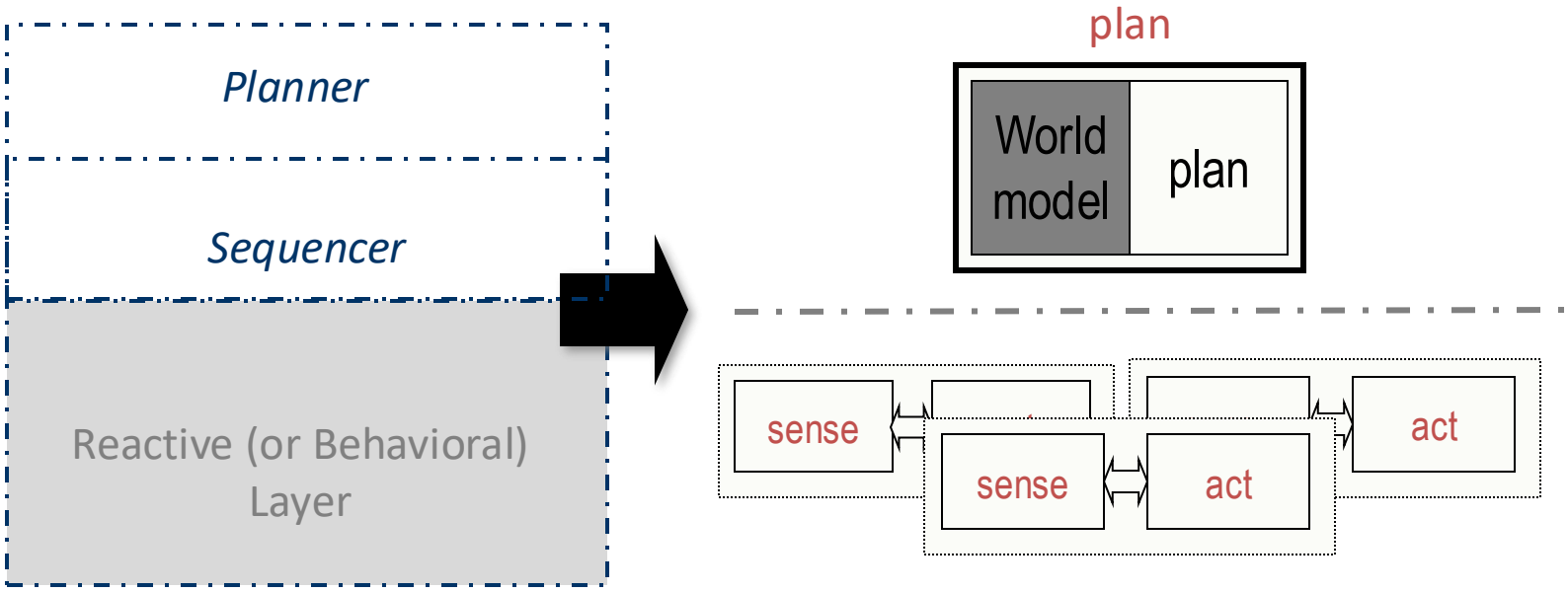
HYBRID (DELIBERATIVE/REACTIVE) PARADIGM



«PLAN, then SENSE-ACT»

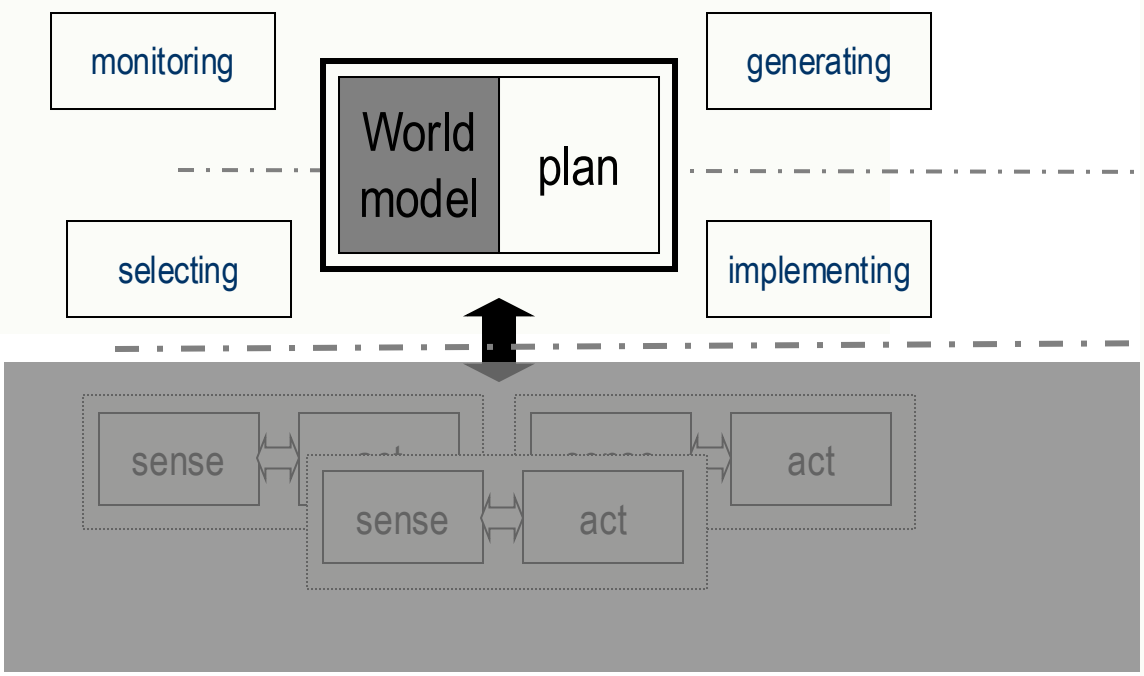
- PLAN, then instantiate appropriate SENSE-ACT behaviors, until next step in plan, …
- PLAN requires a World Model (though it is bounded) plus the actual planning algorithms
- **Reactive layer** requires distributed sensing and reactive functions operating at different time scale from **Deliberative Layer**

Time horizons



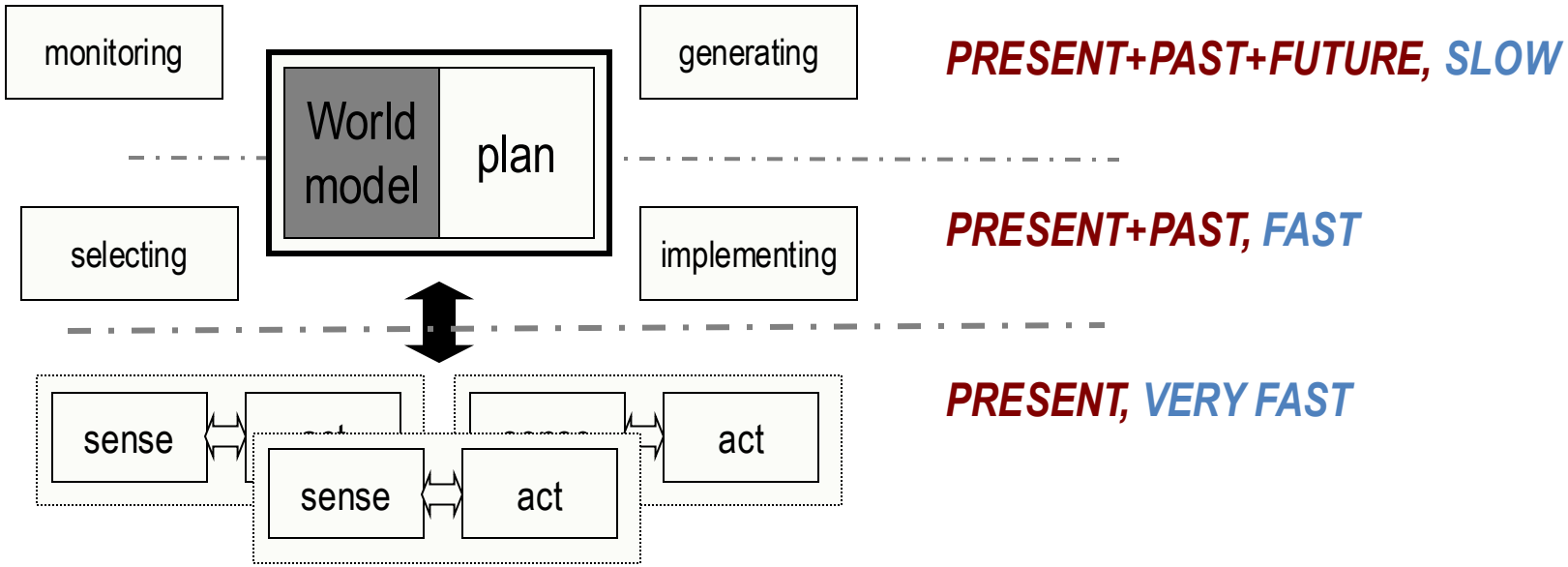
- PLAN, then **instantiate appropriate** SENSE-ACT behaviors, **until next step** in plan, …
- distinct planning horizons, and time scales

Planner and Sequencer



- Upper level (PLANNER)
  - is *mission generation & monitoring*
  - Need Past, Present, Future
- Lower level (SEQUENCING)
  - is *selection* of behaviors to accomplish task (*instantiation*) & local monitoring
  - Need Past, Present

OTHER RAMIFICATIONS: Planning Horizon, Time Scales



ADVANTAGES OF PROGRAMMING IN LAYERS WITH DIFFERENT STYLES

- Decomposition of a complex system
  - Can use a separate processor(s) for each layer or behaviors
  - Can split between on-board, off-board
- Matching right tools and mindset for the task
  - Ex. C++ for behaviors, Lisp for planning
- Incrementally, add new functional modules to working and verified code
- BUT the layers should not suggest that one layer is built first and tested and then the other layers are built on top.

HOW MUCH ARTIFICIAL INTELLIGENCE DOES A ROBOT NEED?

It depends…

- What functions does the robot need to do?
  - Generate? Monitor? Select? Implement? Execute behaviors? Learn?
- What planning horizon does the functions require?
  - Present, Present+Past, Present+Past+Future
- How fast do the algorithms have to update?
  - May have to use a closed world and guaranteed execution rates (control theory)
- What type of model does the robot need? Local? Global? Both?
  - Note: go with the minimum

OTHER OBSERVATIONS

- Current practice is
  - good with deliberative functions operating on symbols,
  - good with behaviours using direct perception
- The major barrier is going from sensory data to symbols: recognition and labelling as unique instances
- Major barrier in understanding human intention (which is often implied but never spoken); AI robots currently require explicit directions

Components of Hybrid Paradigm

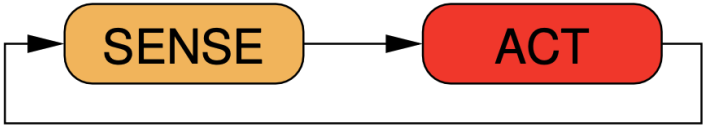
- **Sequencer** – generates a set of behaviors to accomplish a subtask.
- **Resource Manager** – allocates resources to behaviors, e.g., a selection of suitable sensors.
  (In reactive architectures, resources for behaviors are usually hardcoded.)
- **Cartographer** – creates, stores, and maintains a map or spatial information, a global world model and knowledge representation.
  (It can be a map but not necessarily.)
- **Mission Planner** – interacts with the operator and transform the commands into the robot term.
  - Construct a mission plan, e.g., consisting of navigation to some place where a further action is taken.
- **Performance Monitoring and Problem Solving** – it is a sort of self-awareness that allows the robot to monitor its progress.

Summary: The three robotics paradigms

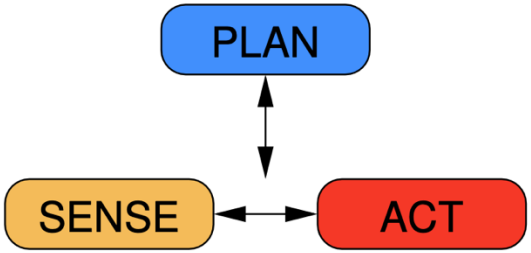
- Robotic paradigms define the relationship between the robotics primitives: Sense, Plan, and Act.
- Three fundamental paradigms have been proposed in the literature.

1. **Hierarchical** paradigm is purely deliberative system.

2. **Reactive** paradigm represents reactive control.



3. **Hybrid** paradigm combines reactive and deliberative.



Adapted from Jan Faigl