

Control architectures

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Objectives

Specific Objectives

- What is a control architecture
- To know main control architectures

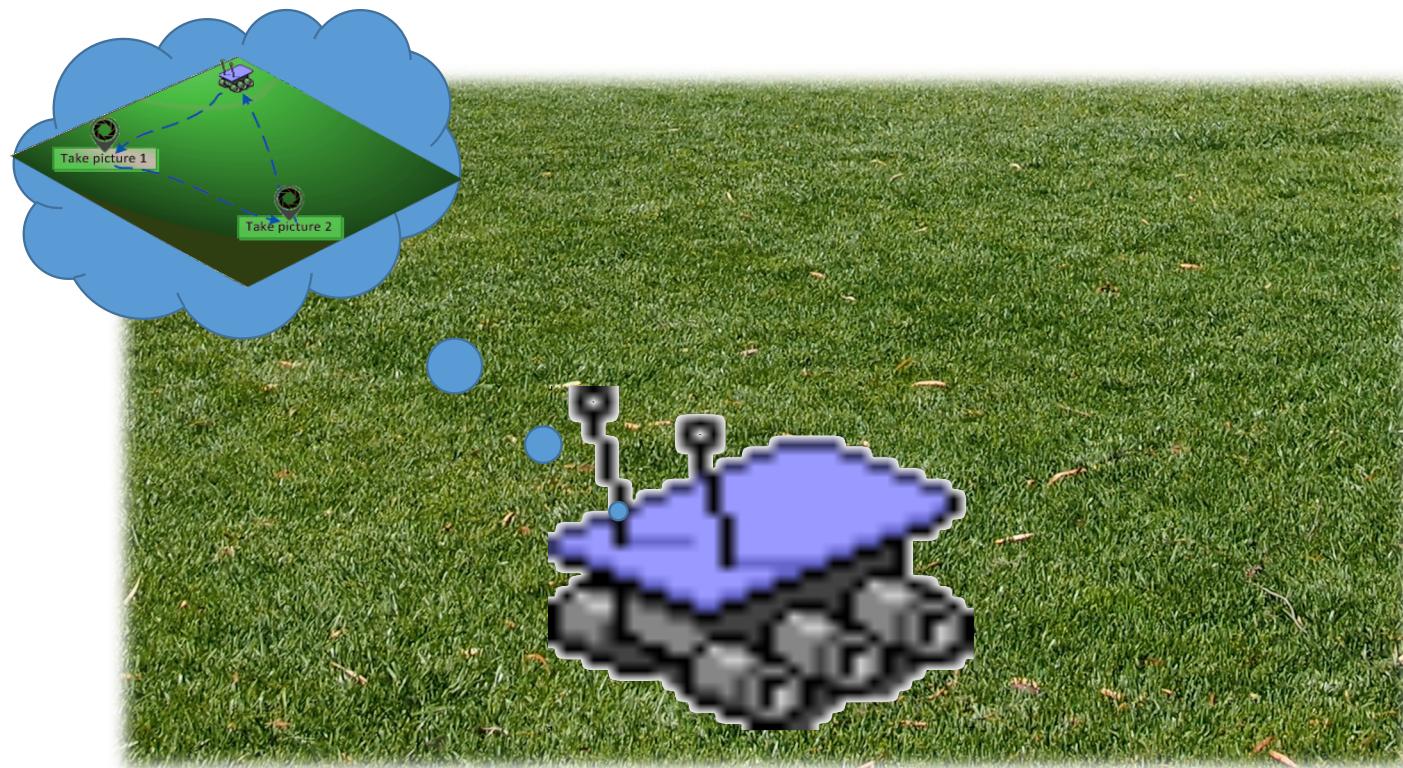
Source

- Stuart Russell & Peter Norvig (2009). Artificial Intelligence: A Modern Approach. (3rd Edition). Ed. Pearson
- M. D. R-Moreno and James Kurien. What is next in Autonomous Control Techniques? ISAIRAS'08.

Outline

- **Introduction**
- Autonomous Control Architecture
- Conclusions

Introduction



Introduction

- Autonomous control architectures use models:
 - To reason about the system that control
 - The environment where they act
- They achieve a set of extended goals over a period of time, and are able to reason about faults with little or no human
- Given the initial state and external goals: they generate a set of actions
- If an action is not executed as expected: “recover”

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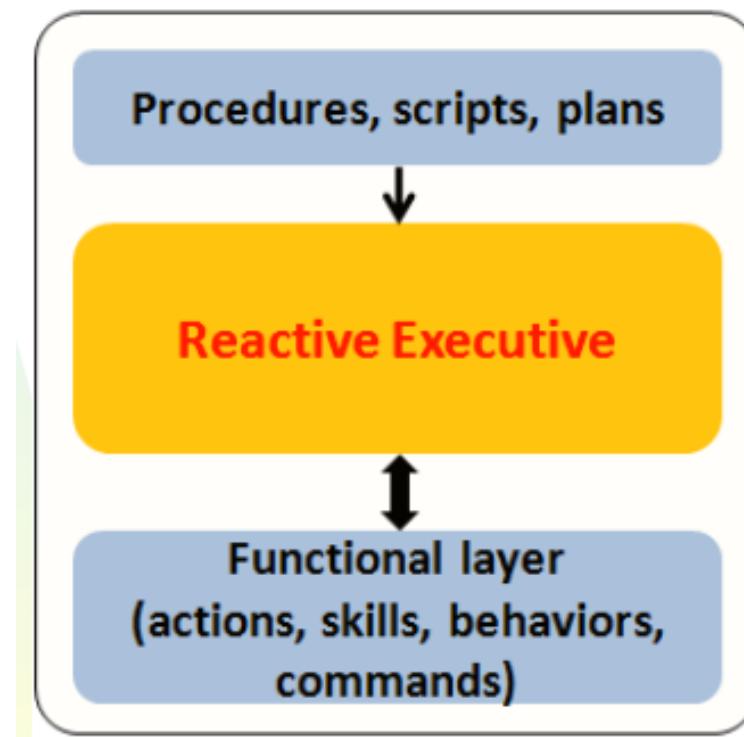
Classification

- Attending to the “**reactivity/deliberativeness**” of the system, the main architectural approaches are:
 - Reactive, procedural approach (non-deliberative)
 - Purely reactive controllers
 - Symbolic reactive controllers
 - Hybrid approach
 - Three-tiered controllers
 - Model-based, planning centric methods

Reactive (non-deliberative)

- **Purely reactive controllers:** motor action as response to the collected data by sensors without reasoning about them (no internal state is contained)
- **Symbolic reactive controllers:** an intermediate “decision-making” step that infers an action output from the sensor input and a symbolic representation is introduced (based on behaviours)
- Suitable when:
 - Real world cannot be accurately modeled
 - Uncertainty is quite delimited
 - Real-time warranty is a safety-critical concern

Reactive (non-deliberative)



Reactive (non-deliberative)

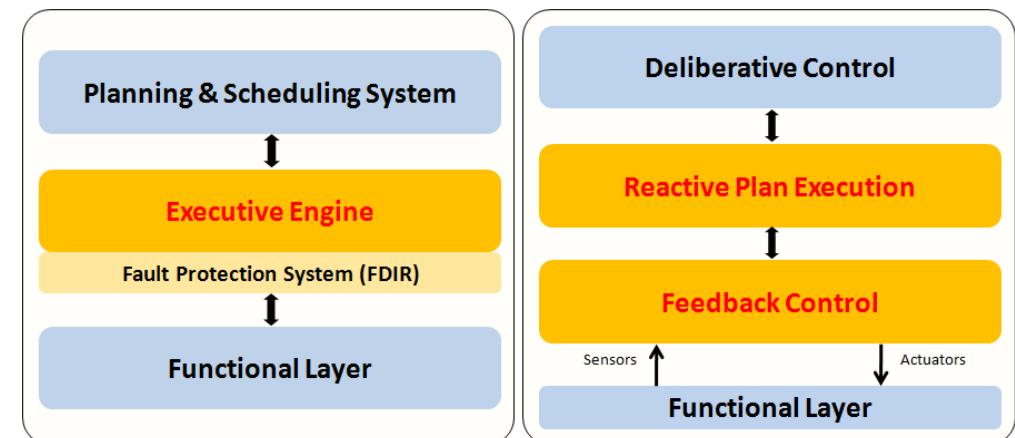
- Examples:
 - Subsumption architecture [Brooks, R.A., 1986]
 - System decomposed into concurrent (hierarchically arranged) behaviors: higher layers represent more abstract behaviors, and have lower priorities than the lowers
 - Behavior: sense-act function which maps perceptual inputs to actions
 - Agent Network Architecture (ANA) [Maes, P., 1991]
 - Similar system decomposition
 - Behaviors modules defined by their pre-conditions and post-conditions (interfaces), and by a (dynamic-valued) activation level

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Three-tiered controllers

- Interleave a planning step using a model of the world
- Implement Sense-Plan-Act cycle
- Limitations:
 - Monolithic planning cycle
 - Slow reactivity when deliberation is needed
 - Hard scalability and robustness decreasing



Three-tiered controllers: examples

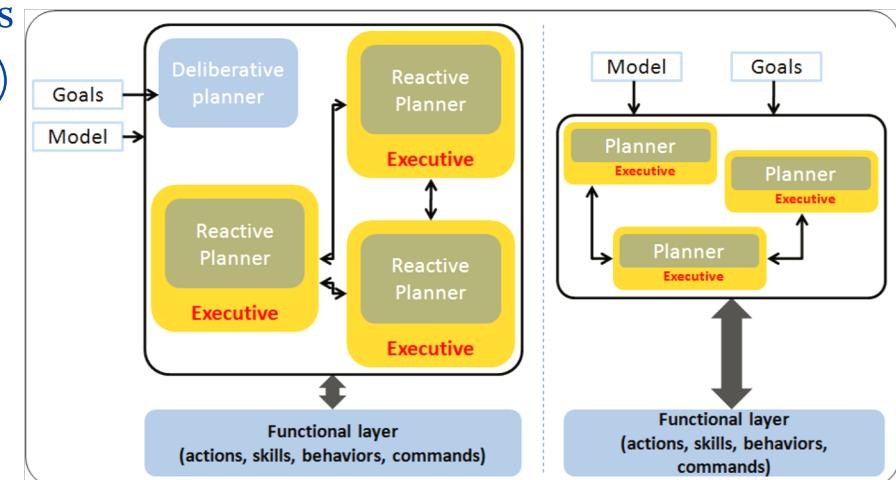
- 3T [Bonasso et al., 1997]
 - 3 layers
- Tripodal Control Architecture [Kim, G. and Chung, W., 2006]
 - Consist of a deliberative, a sequencing and a reactive layer.
 - The deliberative layer is the interface with the user and with the planning process execution
- ATLANTIS [Gat, E., 1992]
 - Consists of a reactive controller, a sequencer and a deliberator
 - Includes monitor capabilities to re-planning/plan-repairing

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Model-based, planning centric methods

- Exploits automated planning and model-based reasoning at the core
- Divide-and-conquer scheme: system functionality is distributed
- Theoretically meets:
 - The efficiency/robustness of the reactive controllers
 - The high-level reasoning capabilities of the (purely) model-based approach

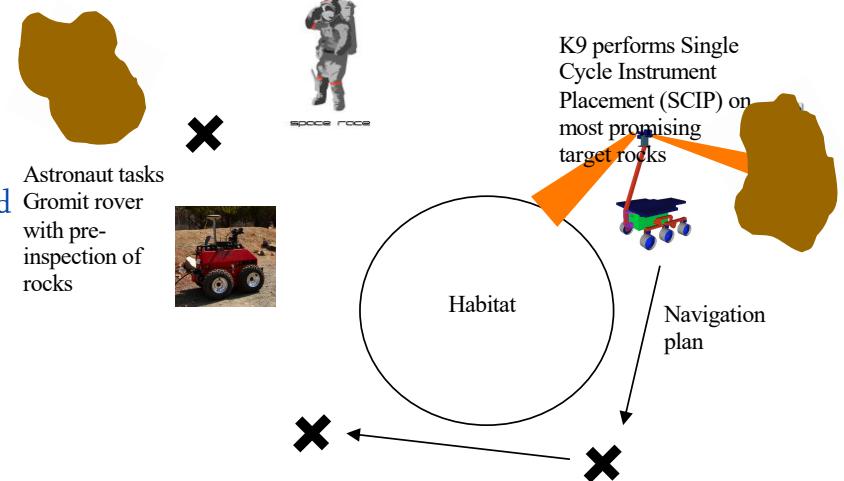


Model-based, planning centric methods: IDEA

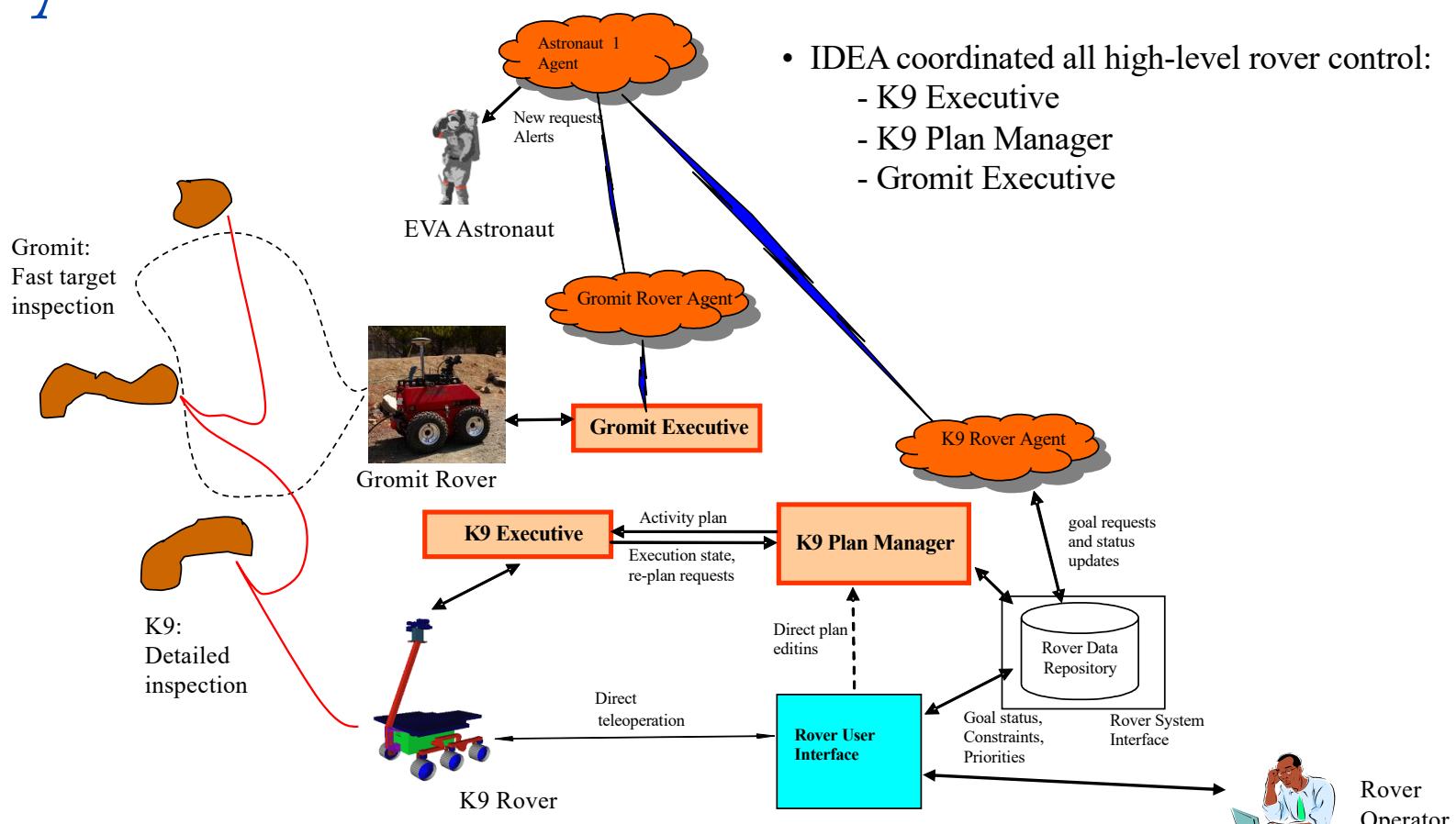
- IDEA is an architecture that enables high-level control by tightly integrating planning and execution
- Interleaved planning and execution
 - AI planning and scheduling is the core reasoning approach for execution
 - Planning over different horizons enables deliberation and reaction in a single framework
- Model-based control
 - Declarative models define system behavior and interactions with other systems
 - Models restrict plan search to legal behavior

Collaborative Decision Systems (CDS)

- Human-robot collaboration for planetary surface operations
 - Gromit rover (rock pre-inspection)
 - K9 Rover (detailed science sampling)
 - EVA astronaut (directing geology)
 - RoverOperator (oversees rover ops)
- Project Goals:
 - Demonstrate coordinated human-robot surface operations near human habitat
 - Coordinated field geology
 - Tightly integrate and test existing technologies
- IDEA K9 Exec and PlanManager
 - PlanManager: turns goal requests from RoverOperator into plans for K9
 - K9 Exec: using plans, oversees mobility, target tracking, instrument placement and measurements
- IDEA Gromit Exec
 - Coordinated mobility and panoramic image taking
- Results Synopsis
 - Successful demonstration of coordinated operations
 - IDEA greatly eased system integration

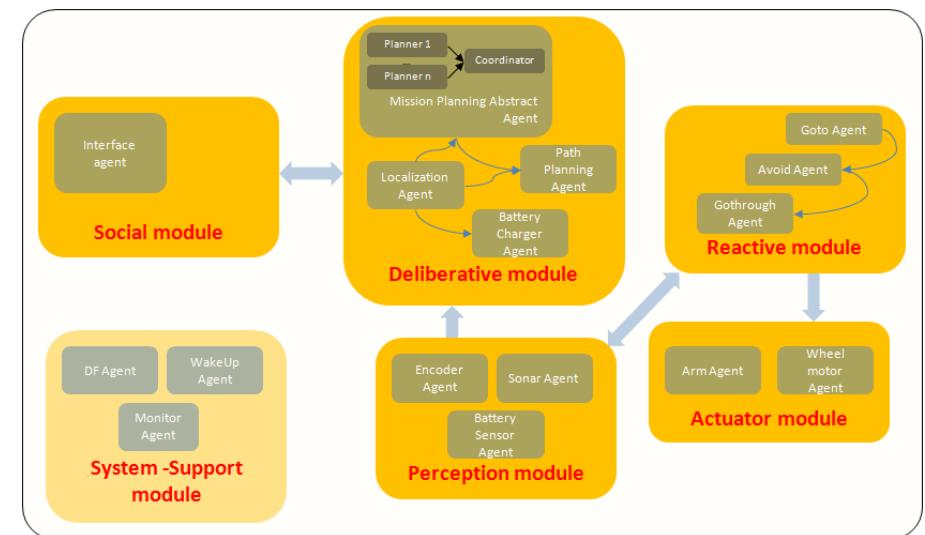


CDS System Architecture



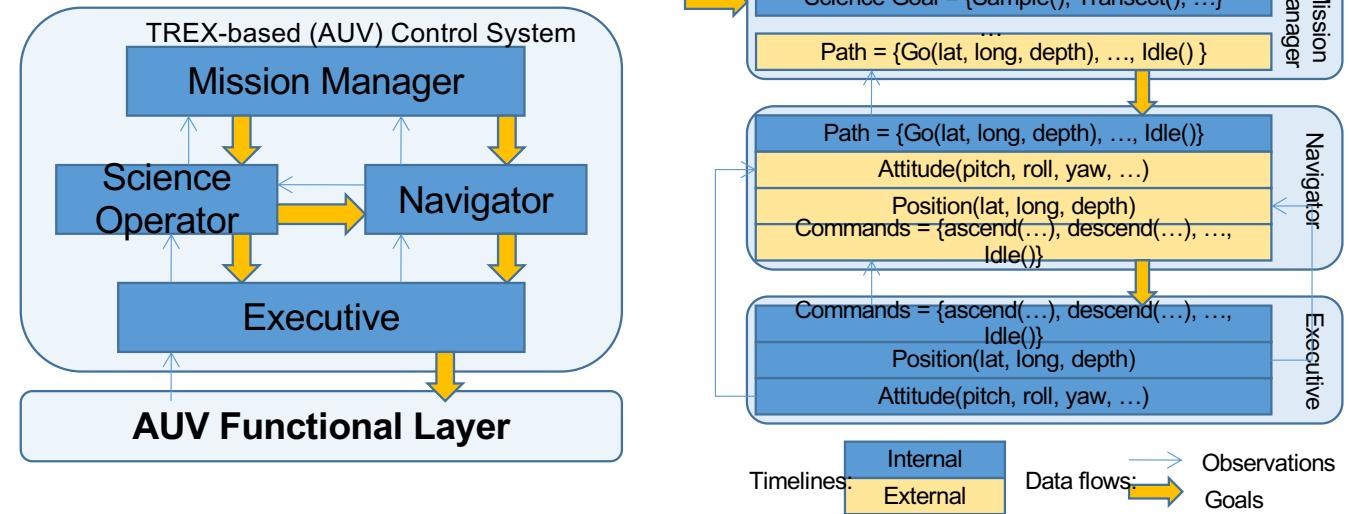
Model-based, planning centric methods: examples (I)

- ARMADiCo [Innocenti, B., 2008]
 - Multi-agent and general purpose architecture for mobile robots
 - Distributed communication scheme which allows agents compete for the available resources



Model-based, planning centric methods: examples (II)

- **TREX** [McGann, C. et al., 2008]
 - Combines goal- and event-driven behavior in a framework based on temporal reasoning & planning
 - Developed for Autonomous Underwater Vehicles



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Conclusions

- A system is autonomous if it is able to achieve their goals with little or no human supervision
- Traditional systems are based on 3T-arquitectures
- New approaches distribute the systems between different controllers

Conclusions

- Where can we apply AI in robotic systems?
 - Navigation and Path Planning (depends on the mission)
 - Planning/Scheduling and Intelligent Execution
 - Command sequence generation
 - Data processing and validation
 - Vision

Conclusions

- What is the desired autonomy level?

Level	Description	Functions
E1	Mission execution under ground control; limited onboard capability for safety issues	Real-time control for nominal operations. Execution of time-tagged commands for safety issues
E2	Execution of pre-planned, ground-defined, mission operations onboard	Capability to store time-based commands in an on-board scheduler
E3	Execution of adaptive mission operations onboard	Event-based autonomous operations. Execution of on-board operations control procedures
E4	Execution of goal-oriented mission operations onboard	Goal-oriented mission re-planning