## IVR: A Brief Outlook to Robot Architectures

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## informatics

- The Sense-Plan-Act paradigm
- Brooks' subsumption architecture
- Three-layer architecture

## Behaviour-based robotics

- Reactive behaviours
- Embodied intelligence
- Action-relevant sensory information processing
- Minimal processing, representation, control
- Modular, hierarchical, distributed control





SPA is

- serial
- ad hoc
- analytical
- assumptious

SPA lacks:

- speed and efficiency
- flexibility and adaptivity
- modularity and scalability
- error-tolerance and robustness

- Direct coupling of perception and action. Aim is timely robotic response in dynamic and unstructured worlds. Typically in the context of motor behaviours.
- Reactive control architectures will be discussed on more detail with the behaviour based control architectures.
- One of the prominent examples for reactive control is the subsumption architecture (see below).

Rodney Brooks: "Fast, Cheap & Out of Control" (1997)

Some considerations that (according to Brooks) can be helpful:

- Planning is just a way of avoiding figuring out what to do next.
- The world is its own best model
- Complex behaviour need not necessarily be the product of a complex control system
- Simplicity is a virtue
- Robots should be cheap
- All on-board computation is important
- Systems should be build incrementally
- Intelligence is in the eye of the observer
- No representation, no calibration, no complex computers

Some objections that can be misleading:

- In a different environment the robot will fail!
   "A function that deals with this problem will create more problems"
- The system cannot be debugged!
  "Pure teo are in the available."
  - "Bugs, too, are in the eye of the observer"
- It's not scalable!
  "Elephants don't play chess"

http://people.csail.mit.edu/brooks/index.html

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- "I wouldn't want one to be my chauffeur" (C. Torpe)
- Modifications at low-levels affect higher levels
- Often there the hierarchy is not strict and conflict may arise
- Priorities rather than inhibition
- Representations, plans, and models do help
- Reproducibility is a virtue
- SPA is top-down, Subsumption Architecture is bottom-up
- "neats vs. scruffies"

- $\bullet \quad \text{Hierarchical: Sense} \rightarrow \mathsf{Plan} \rightarrow \mathsf{Act}$
- 2 Reactive: Sense  $\leftrightarrow$  Act
  - Usually no planning
  - Generalises to behaviour-based architectures: Several parallel reactive loops that are activated by particular inputs or goals
  - Includes subsumption architecture
- Hybrid deliberative/reactive: reactive loops are selected, scheduled and modified according to a high-level representation that includes planning components

Deliberative	Reactive
symbolic	reflexive
needs internal representation	no internal representation
complex digital computation	simple analogue computation
slow responses	real-time responses
near-complete world model	embedded
artificially intelligent (cognitive)	low-level intelligence



Planning, search, reasoning standard programming, time consuming computations

Competition, scheduling, and adaptation of behaviours, reactive plan execution

Elementary reactive behaviours

R. James Firby 1990. Erann Gat, 1998

- Schemata (M. Arbib)
- Circuit architecture: Situated automata (L. Kaelbling)
- Action selection (P. Maes), behaviour-based robotics (R. Arkin)
- Dynamical systems, metaheuristic control, neuro-control
- Cognitive architectures

- Simplicity is a virtue
- The subsumption architecture is simple and extensible and often makes a good start
- The ultimate goal is to interface automatic reasoning with the real world
- Limited resources, unreliable sensors, unpredictability and complexity of the environment are problems for any approach to robot control
- Solution of the second seco

