On the Concept of Autonomy

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Outline

- Robots and autonomous machines.
- Autonomy and complexity.
- Examples.
- Conclusions.
A General Definition of a Robotic System

- A machine endowed with four basic capacities:
  - *Data acquisition* through sensors.
  - *Data interpretation*: to extract information and build representations from acquired data and pre-existing knowledge.
  - *Decision-making*: using information and knowledge to determine and plan a course of action, to achieve an objective or to react to events.
  - *Action execution* in the real world through actuators or other devices.

- Two additional capacities
  - *Communication* with operators, users, or other machines.
  - *Learning* to improve world representations or action performance from experience.
Remarks

- These capacities may be developed up to different degrees of complexity.
- They may be integrated in a single “body” or distributed.
Autonomy

- Capacity of a system to decide and act without the assistance of another agent
- Autonomy can be defined in relation to the aforementioned capacities and their integration.
- Operational autonomy:
  - Related to data processing to build basic representations such as terrain models, and motion/action control, e.g., to follow trajectories and avoid obstacles.
  - Widely present in today’s deployed system
- Decisional autonomy
  - Related to reasoning on perception and action, to assess situations and take non trivial decisions.
Autonomy is a relative concept

- The feasible autonomy is related to the complexity of the environment and of the task.

- Complexity of the environment can be measured by the quantity and rate of information processed by the sensors.

- Complexity of the task is related to the dimension and structure of the state space.

- There is a continuum between the deterministic and predictable automaton and the autonomous system.
Examples

Semi/Autonomous

Autonomous

Teleoperated: Human control
State of the Art

- Operational autonomy is achievable in a large set of situations, with some limits (e.g., navigation, mapping, localization).

- Decisional autonomy is possible in simple problems and situations:
  - Poor interpretation and situation assessment due to uncertainties and fundamental problems in scene and object recognition.
  - Complexity of planning and decision-making

- Learning: an optimization problem limited to simple skills and actions.
Structure of an autonomous system

Decisional autonomy

Operational autonomy: data processing and action control.

Formally, an automaton

Sensors and actuators
Example: Autonomous Flight and Terrain Mapping
Example: Navigation

Road following

Local navigation

Trajectory planning

Easy terrains

Rough terrains

Navigation strategy

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Structure of an autonomous system

- **Decisional autonomy**: (replaced by a human)
- **Operational autonomy**: data processing and action control.

Formally, an automaton

S0 → S1 → S2 → S3 → S4 → S0
Decision Making

- Preprogrammed procedures selected according to context and goal.
Conclusions

- Autonomy is a relative notion

- Automated (not autonomous) systems exist and are able to achieve a wide variety of (simple) tasks in simple environments.

- Realistic complex tasks and dynamic situations require capacities for real time situation understanding and decision making not achievable in the near future.