A Systematic Method of Designing Control Systems for Service and Field Robots

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A systematic approach to the design of control systems for robots executing complex tasks will be presented. Each robot is treated as an embodied agent, i.e. an entity influencing a physical environment by its effectors, gathering the information about the state of this environment through its receptors (sensors), and using that information in a decision process to execute a task that is its internal imperative. The design method is based on a design pattern resulting from the decomposition of an embodied agent into: real effectors, real receptors, virtual effectors, virtual receptors and a control subsystem. Virtual effectors are introduced to present to the control system the real effectors in such a way that task formulation is kept at an acceptable level of complexity. By the same token virtual receptors are responsible for sensor reading aggregation into a form that can be readily used by the control subsystem during the task execution. In other words, virtual entities, through an adequate transformation, represent real entities in an ontology that the control subsystem accepts. The mentioned entities contain an internal memory and input and output buffers through which they communicate. Their internal functioning is governed by transition functions that take the contents of the internal memory and input buffers as arguments to produce new contents of the memory and the output buffers. Iterative execution of transition functions combined with input and output of data from/to other entities results in a behaviour. Behaviour terminates its execution when a terminal condition associated with it is satisfied. The choice of the next behaviour is made based on initial condition. As a consequence the initial and terminal conditions govern the execution of the behaviours, i.e. a finite state machine is formed, with the behaviours being associated with the nodes of its graph and the mentioned conditions forming its state transition table. Embodied agents can communicate with other agents, either embodied or not, through input and output buffers located in their control subsystem, thus the design method can be used to produce multi-robot systems. As the contents of the buffers, memory can be represented formally, and the transition functions can be defined mathematically, while finite state machines have also a rigorous representation, a formal method of specification results. As transition functions can be directly transformed into functions of any imperative type of a programming language, with the contents of the memory and buffers represented in the form of their data structures, the transformation of that specification into implementation code is straightforward. Usually implementation is carried out by utilizing some robot programming framework, e.g. MRROC++, ROS, OROCOS, DisCODe..

This presented method has been applied to the design of several robot control systems. As its illustration the design of the control system of a two-handed robot with a movable torso and head executing manipulation tasks will be presented. The manipulators use position-force controllers, while the head uses cameras and Kinect sensors for object recognition and localization. To acquire objects visual servoing is used. The manipulators are terminated by three-fingered grippers. Such a robot can be mounted on a mobile base capable of propulsion on flat surfaces, thus suited to home environments, hence the described robot can execute service tasks, or, e.g., can be mounted on a multi-legged base, which can operate outdoors, thus transforming the device into a field robot. The control system design remains the same for both cases.