

RoboCupRescue 2006 - Robot League Team ALCOR (ITALY)

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Abstract. We present a stable and autonomous system based on a strong interaction between visual cognitive inference and actions executed. Mapping, Vision and Navigation are all collaborative agents that work together sharing data to accomplish to complex identification and mapping tasks. The visual process reacts to interesting features in the arena trying to approach the focused area in order to achieve more successful observations from the environment. This activity is performed coordinating the states that model the robot actions in the arena.

Introduction

We present in this competition an approach to robot-control that we define model-based control of attentive robots.

Given the complexity and risks entailed by a rescue mission, both human and robotic abilities must be combined and deployed. Therefore, a control architecture tailored to a rescue domain is to provide not only autonomy, but also an effective smooth interaction between the operators and the robotic system. In this scenario, the system execution needs to be continuously monitored allowing for human operator interventions whenever these are required. In particular, the control system is to sup-

port the operator by: i. autonomously performing complex tasks (autonomy); ii. providing an intuitive and effective view of the robot current status (situation awareness) both internal (executive) and external (environment); iii. enhancing the attention and focusing it on relevant facts/features/decisions (attentive control).

There have been several efforts to establish the essential aspects of human-robot interaction, given the current findings and state of the art concerning robot autonomy and its modal-abilities towards humans and environments (see [4] specifically related to the rescue environment). It is therefore crucial to model the interaction in terms of a suitable interplay between supervised autonomy (the operator is part of the loop, and decides navigation strategies according to an autonomously drawn map, and autonomous localization, where obstacle avoidance is guaranteed by the robot sensory system) and full autonomy (e.g. visual information is not reliable because of darkness or smoke etc., and the operator has to lean upon the robot exploration choices).

Our aim is to introduce a control system which continuously coordinates, integrates, and monitors the modules initiatives and decisions about the ongoing functional activities (including the operator arbitration) taking into account the overall mission goals and constraints. The control system we are describing is a fully autonomous system that can also easily dialog with the operators and is “docile” in the case of an intervention. In other words, the system is to seamlessly support all the operative modalities ranging from a completely autonomous behavior to the teleoperated one.

In order to allow the tight interaction described above, we have designed a control system based on a reactive planning activity. More precisely, we developed an interactive control system which combines the following features:

- **Attentive control.** The control system activity is continuously influenced by attentive processes: some of the control modules, called decision daemons, are autonomous decision makers whose behavior can be attracted by salient features recognized in the external/internal environment (e.g. image features, interesting space regions, salient observation points etc.). In this way, attention to saliency works as the main stimulus that can polarize the activity of the system. In particular, we consider attentive exploration, that is, we derive a saliency map of the environment from visual features, and let it attract the robot towards interesting spots. The saliency map is a generative response to the environment as it leads to exploration choices propagated by perception and generating other behaviors. The saliency map construction determines the decision daemons cooperation towards an overall attentive behavior that drives and focuses the exploration of the environment. On the other hand, the decision daemons processes are to be integrated and harmonized by the monitoring (model-based) system in order to avoid conflicts: the decisions modules are treated as suggestions the monitoring system can accept or inhibit trying to keep a consistent and persistent global behavior.

- **Model-based control.** The control system is endowed with declarative models of the controllable activities, where causal and temporal relations are explicitly represented (like, e.g., in [5]). In this way, hard and soft constraints can be directly encoded and monitored. Furthermore, formal methods and reasoning engines can be deployed either off-line and on-line, to check for consistency, monitor the executions, perform planning or diagnosis. In a mixed-initiative setting the aim of a model-based system is twofold: on the one hand the operator activities are explicitly modeled and supervised by the control system; on the other hand, the model-based monitoring activity exports a view of the system that is intuitive and readable by humans, hence the operator can further supervise the robot status in a suitable human robot interface.
- **Reactive executive monitoring.** Given this model, a reactive planning engine can monitor both the system's low-level status and the operator's interventions by continuously performing sense-plan-act cycles (as for other executive systems based on reactive planning, we mention [1]). At each cycle the reactive planner has to: (i) monitor the consistency of the robot and operator activities (with respect to the model) managing failures; (ii) generate the robot activities up to a planning horizon. The short-range planning activity can also balance reactivity and goal-oriented behaviour: short-term goals/tasks and external/internal events can be combined while the planner tries to solve conflicts. In this way, the human operator can interact with the control system through the planner in a mixed initiative manner.
- **Flexible interval planning.** At each execution cycle a flexible temporal plan is generated. Given the domain uncertainty and dynamics, time and resources cannot be rigidly scheduled. On the contrary, it is necessary to account for flexible behaviours, allowing one to manage dynamic change of time and resource allocation at execution time. For this reason the start and end time of each scheduled activity is not fixed, but the values span a temporal interval.
- **High-level agent programming.** The high-level agent programming paradigm [3] allows one to integrate procedural programming and reasoning mechanisms in a uniform way. In this approach, the domain first principles are explicitly represented in a declarative relational model, while control knowledge is encoded by abstract and partial procedures. Both the system's and the operator's procedural operations can be expressed by high-level partial programs which can be completed and adapted to the execution context by a program interpreter endowed with inference engines.

1. Team Members and Their Contributions

- Fiora Pirri Visual Cognitive System.
- Andrea Carbone Operator ,Vision algorithms, Navigation, Software Design.
- Giorgio Ugazio SLAM, HRI, Metric Path Planning
- Alberto Finzi Golog Planner.
- Andrea Orlandini Golog Planner
- Anna Belardinelli Attentive Gaze System, Vision algorithms.
- Alessio Pascucci Learning.
- Francesco Scialacqua System Integration.
- Stefano Marra Laser scan and 3d camera fusion.
- Andrea Reale Hardware and Electronic supervisor.
- Francesco Roccucci Attentive Navigation.

2. Operator Station Set-up and Break-Down (10 minutes)

The payload set-up, both for Doro and SecuRo, requires few steps to be performed. They consist on: turning on both the operator's laptop and the remote one followed by the bootstrap of the onboard Platform Services. After these steps, each other module (including the operator) gains control permission over the Robot and can start the exploration of the targeted arena. On top of the robotic platforms, the payload devices (cameras, pan-tilt and telemeter) are all connected to the on-board laptop. All is kept together by a plastic support which contains the laptop and all requested cables and power supply adapters. ActivMedia Pioneer robot is provided with an external handle on the rear in order to let the operator to bring it up and transport like a bag.

3. Communications

The laptop mounted on the top decks of our robots are equipped with an **802.11A** wireless PCMCIA devices. These provide access to all the on-board activities via a remote monitoring using an operator laptop which is connected in a peer-to-peer manner with the robots laptop. A wireless router will provide the link between field robot and the operator station. We are going to use standard C class 192.168.10.x addresses.

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MODIFY TABLE TO NOTE <u>ALL</u> FREQUENCIES THAT APPLY TO YOUR TEAM		
Frequency	Channel/Band	Power (mW)
5.0 GHz - 802.11a	any	as requested from the local committee
2.4 GHz - 802.11b/g	any	as requested from the local committee

4. Control Method and Human-Robot Interface

In this section we describe our Control System, Communication System, Interaction System and our operational modes on both Doro and Shrimp robots.

We introduce a control architecture where decision processes (including declarative activities and operator's interventions) are tightly coupled with functional processes through a model-based executive engine. The figure below illustrates the overall control architecture designed for our rescue robots.

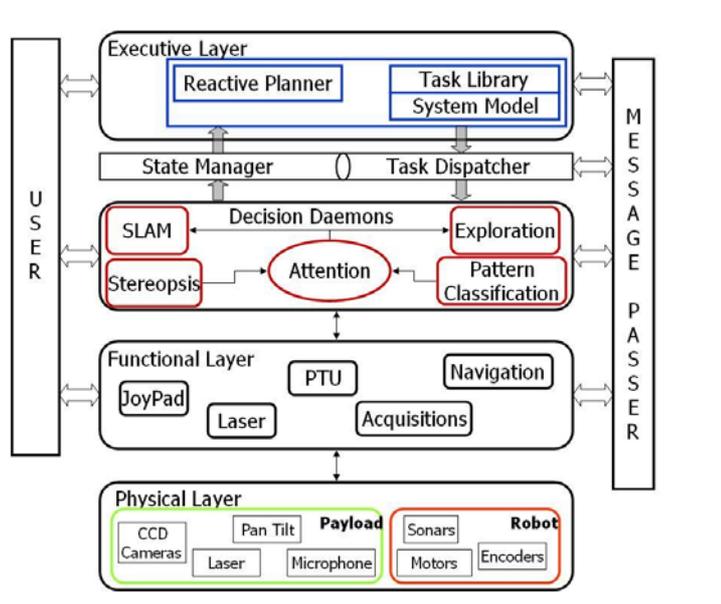


Figure 1 - Control Architecture

A. Physical layer

The physical layer is composed of all the robot devices, i.e. motors, sonars, and payload.

B. Functional modules

The functional level collects all the robot basic capabilities. Our control system is endowed with the following modules: Navigation, Acquisitions, Joypad, Laser, and PTU. The Navigation module controls the robot movements. Elementary reactive behaviors are provided by this component, e.g. obstacle avoidance, wandering, moving toward a target location. The Acquisitions module manages the procedures needed to collect data from sonars, laser, and cameras and present them to the other modules. The Joypad is the functional interface between the robotic system and the human operator, e.g. it allows devices teleoperation and direct motion commands. Laser, and PTU modules control the corresponding physical devices (Telemeter and pan-tilt unit) by means of atomic actions.

C. Decision daemons

Decision daemons are responsible for the attentive behavior, they are special modules collecting data from the functional layer and providing interpretations and some (mostly low-level) decisions. A distinctive characteristic of the decision daemons is that they are all involved in the attention process: they provide information about the environment associated with salience values or suggestions about salient features. Applying several techniques, daemons cooperate at the saliency map construction and produce some suggestions about interesting locations in the arena and whether additional exploration/elaboration is needed or not. The SLAM daemon builds a map of the explored area collecting the sensors readings and continuously localizing the robot position. The Exploration daemon is responsible for defining the exploration strategy taking into account the information passed by the other modules. Visual processing is performed by the Stereopsis and the Pattern Classification daemons. The Stereopsis provides the processes needed for stereo vision (e.g. image stereo-correlation and 3D map) and cooperates with the Pattern Classification task to detect salient regions of the visual images. Pattern Classification deploys several methods to perform victim detection and identification. Finally, the Attention daemon is responsible for the overall attentive process, it produces the saliency values that are integrated into the saliency map.

D. Overall communications

The state manager and task dispatcher in the figure are designed to manage communication between the executive and decision layers. The state manager gets from each single daemon its current status in order to collect the status of all of them, continuously updating its information. The task dispatcher sends tasks activation signals to the daemons upon receiving requests from the planner or the human operator. This structure is based on TCP technology and let communicate all components of the system.

E. Executive Layer and computational cycle

We rely on a model-based executive control system which supervises and integrates the robot modules activities. Following this approach, the main processes (e.g. mapping, laser scanning, navigation etc.) are explicitly represented by a declarative temporal model that permits a global interpretation of the execution context. Given this model, a reactive planner can monitor the system status and generate the control sequences by continuously alternating sensing, reactive planning, and execution. The overall computational cycle works as follows: the planner gets the daemons and functional modules status querying the state manager. Once the state manager provides the execution context, the planner produces a plan of actions and yields the first set of commands to the task dispatcher. In the execution phase, each daemon reads the signals and starts its task modifying its internal status and requesting some data or action by functional modules (also them modifying their status). At the next cycle start, the planner reads the updated status through the state manager and can check whether the tasks were correctly delivered. If the status is not updated as expected, a failure is detected, the current plan is aborted and a suitable recovery procedure is called.

F. User interaction

The human operator can interact with the control loop both during the plan and the act phase. In the planning phase, the operator can interact with the control system by (further details are given in [2]): (i) posting some goals which are to be integrated in the partial plan already generated; (ii) modifying the generated plan through the user interface; (iii) on-line changing some planning parameters, like the planning horizon, the length of the planning cycle, etc.. In the executive phase, the user can directly control some daemons (e.g., deciding where the rover is to go, or when some activities are to stop). In this case, the human actions are assimilated to exogenous events the monitoring system is to manage and check. Finally, the operator's actions can be accessed by the state manager, and, analogously to the decision daemons, can be monitored by the model-based control system. In this way we realize a gradual variation from totally teleoperated to a totally autonomous system. In particular, DORO control system allows an overall autonomous behavior but operator can supervise the robot activities. The only effort requested to an operator is to familiarize with all the signals and controls provided by the user interface. Instead, SecuRO robot is more suited for teleoperation and its user interface gives the operator a complete control over the robots.



Figura 1 Doro and Securo at the starting line in Osaka

5. Map generation/printing

We conceive two levels of mapping: the Global Map (GM) and the Local Map (LM), the latter is obtained at each SLAM-cycle, via sensor fusion; the Local Map is incrementally integrated into the Global Map, exploiting the well known Bayesian approach. Integration follows a correct alignment of the robot with the map, suitably reviewing odometric errors.

To make the map worth for the operator, so that he can follow the path pursued so far, and verify whether some possible thread has not yet been visited, we introduce two concepts the History Path and the Exploration Path, the first displays the whole path threaded from the very beginning, and the latter makes evident the last steps taken. A typical scenario where the paths are useful is when it is necessary to draw conclusions like “this area has already been visited”, “the victim currently observed is inaccessible from this path, take a snapshot and try to reach it from another way”, and so on.

Furthermore, we are working towards the integration of the 2D global map generated by the SLAM algorithm, with a 3D map obtained by sensor fusion of different sources of range data (note that only Doro has an embedded range device). More specifically, we are using a laser range sweeper and a stereo camera.

The Slam System is a complex daemon producing motion commands and a metric map. The map can be saved in common format (such as JPG or PNG) and contains the Occupancy Grid, Metric Information, Robot Path, Victims found and other things.

useful for human rescue operator. Additional information will be added if considered useful by the operator directly using the client interface.

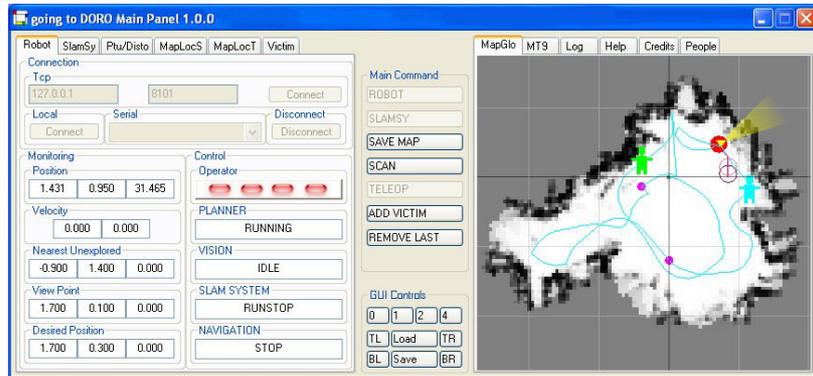


Figure 2 Snapshot of our GUI

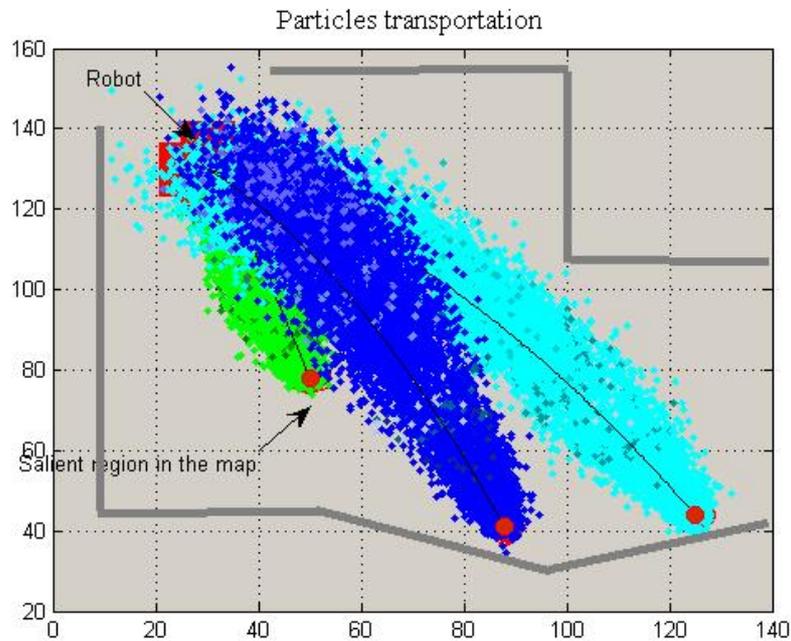
6. Sensors for Navigation and Localization

Both DORO and SecuRo are endowed with Laser Scanners and Stereo-cameras. The pioneer (DORO) is also equipped with 8 Sonar ranging 180° in forward direction. The sensor data are fused and mapped into local occupancy value. These must be integrated in time to build a single, global, Metric Map using a Bayesian Filter that is a recursive estimator we use to calculate sequences of posterior probability distribution over a quantities which cannot be observed directly. The final result is a matrix of cells each representing the probability of being occupied.

On top of the metric map produced by the SLAM system, a saliency map is integrated to provide directions for the attentive navigation. In fact, the saliency map distributes, according to a specific advection-diffusion process, weights on the metric map, and thus “interesting regions” become hotter. Chasing the hottest regions, the robot can approach areas in the scene from which it can start a decision process concerning all the devised interesting elements, i.e. all those regions that have been surmised as

possible

victims.



7. Sensors for Victim Identification

The sensors devoted to victim identification are the camera and the laser range scanner. The visual inference stages are composed of different perceptual stages which goes from an attention phase, in which an interesting 'feature' in the environment catches the attention of the agent, to a cognitive inference based on further observations which are taken into account to guess if all perceptual data collected can lead to a success in the identification of a specified target. The visual process is carried by means of dedicated image analysis routines that can be grouped in more stages like: segmentation/clustering, edge finding, features extraction and others.

The victim identification process determines the exploration strategies through the saliency map construction. In fact, the same techniques are used both in the attention process and in the victim recognition phase: the attention process is more rough since it is to provide only saliency values, while during the victim recognition phase more accuracy is needed in order to lead the system to a decision and resolve a region.

8. Robot Locomotion

No modifications has been done to the original ActivMedia and Bluebotics design for what concerns the locomotion.

9. Team Training for Operation (Human Factors)

The user interface gives the operator a complete control over the robot. So just a basic training in an artificial arena will be useful to take confidence with the controls. Our aim is to build an autonomous system, so the only effort requested to an operator is to familiarize with all the signals and controls provided by the user interface.

10. Possibility for Practical Application to Real Disaster Site

Being based mostly on vision, this system can be highly useful to bring the attention of a remote operator toward specified location of an area that the visual inference system evaluates as a candidate for a rescue action. Basing on the same process the developed visual inference can be applied to a wide range of task that can help a rescue operator to gain informations about the operative condition in a disaster area.

11. System Cost

The economic effort requested by the devices ranges from 8000€ to 10000€ The main cost can be accounted for the mobile robot (half of the overall cost). The entire set is composed by:

- ActivMedia Pioneer 3DX €6000
- Bluebotics ShrimpIII €8000
- Mini Laptop JVC 'mini note €2300
- Laptop Asus centrino (@1.6GHz) €1600
- Direct Perception PTU €2200
- Xsens MT9B Inertial Platform €2000
- Hokuyo Laser Range Scanner €1500

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