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Abstract:

In GruVA, we are interested in developing biologically inspired autonomous robots. The group's main contributions are on behaviour-based models for action selection as well as for locomotion control, topological and metric models for mapping and localisation in dynamic environments, tele-operation and teamwork for critical tasks, and more recently on robotic vision for obstacle detection and localisation. Besides all theoretical developments, the group has been involved in practical projects in partnership with industry, in particular in the context of humanitarian demining.

LabMAg
laboratório de modelação de agentes

Detailed research information:

Robotics research in GruVA follows the idea that engineering can profit considerably from our understanding on the underlying principles of Nature, in particular the ones related with self-organisation. Distributed approaches are thus crucial in our design principles, which include agent-based design, swarm systems, behaviour-based decomposition, consensus mechanisms, among others. In the context of autonomous robots, the GruVA is partner of other institutions, such as UNINOVA from the New University of Lisbon and the company IntRoSys, S.A.. This partnership resulted in the development of Ares, a highly compliant middle-size robot with four independently steered wheels. This robot has been design primarily for Humanitarian Demining tasks, but its application domain can be extended to cover tasks as surveillance and search & rescue.

Fig.1 – The Ares robot performing in all-terrain.

Robustness is pivotal for robots operating in all-terrain environments. This demand arises mainly from the highly heterogeneous and unstructured nature of the terrain. Two particular topics are sensitive to this problem: locomotion control and wheel odometry. A behaviour-based approach has been proposed for the locomotion control system, allowing the system designer to shift the focus from optimality to robustness. In all-terrain environments, the robot is highly likely to find itself performing in extreme situations, thus requiring an exception-oriented design. The fact that the Ares robot is endowed with four independently steered wheels, with a consensus mechanism where each wheel votes for the motion of the robot, enables the use of wheel odometry in off-road.

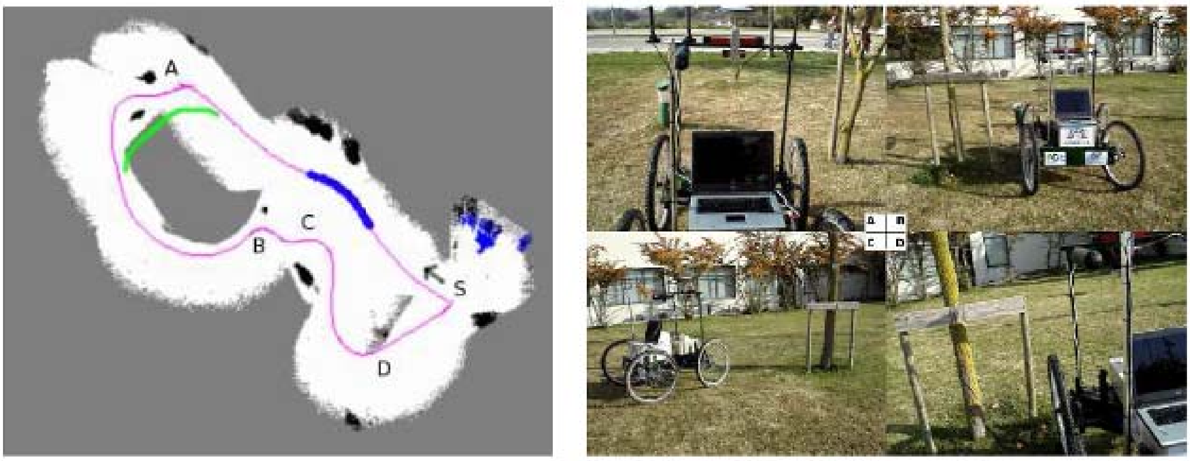

Fig. 2 – Resulting 33m x 27m map produced by the robot while autonomously following a given path (left). Only wheel odometry and compass information were used. Both starting and ending points of the path are in location S. Black, white, and dark grey pixels represent obstacles, non-obstacle regions, and unmapped regions, respectively. The closed-loop line represents the estimated location of the robot during the run. Snap-shots of situations A, B, C, and D (right).

Wheel odometry eventually fails and thus other localisation techniques must be also considered. In addition to the usual application of global localisation techniques, such as GPS, we have also been studying the use of visual odometry for motion estimation. This technique, which in our case makes use of stereo vision, can be highly accurate, with the additional advantage of permitting an exact synchronisation between localisation and visual information, promoting this way more accurate maps. A key aspect of visual odometry is the process of matching image salient features across frames, which tends to produce a considerable amount of outliers. Our model departs from previous work by proposing a heuristic voting algorithm which does not need to generate rotation hypotheses, nor to assume that the robot is moving on a planar surface.

We have also been developing of a robust and fast obstacle detector for all-terrain environments. The proposed algorithm operates on a 3-D point cloud provided by a stereo vision sensor. In order to enable real-time performance and to raise the level of robustness to noise, voting filters and space-variant resolution mechanisms have been put in place. Of particular interest is the innovative use of visual saliency to focus the detection in most prominent regions of the environment, and consequently improve on both computational efficiency and resilience against false positives. Research on the development of a swarm-based approach to the problem is ongoing. In this approach, swarm elements are agents inhabiting the visual input, which are modulated by the action selection process, aiming a dramatic reduction in terms of computational cost. Using the army-ants foraging metaphor, i.e. exploiting self-organisation, we have shown in this work that it is possible to reduce computational cost and even implement sparse, distributed and active environment representations. Ground-plane estimation is also an essential task for a robot performing in all-terrain. We have been working on this topic by proposing the use of visual saliency to modulate the estimation process. As for the obstacle detection case, saliency helped on the reduction of computational cost and on the improvement of robustness.

Fig. 3 – Stereo-based obstacle detection results. Each colour represents a different obstacle.

Having the navigation and piloting problems solved, robots will start facing higher level problems, which will demand behavioural richness. Our group has a long history on this topic, with the proposal of three behaviour-based architectures. In the first proposal, behaviours have been decomposed in action and activity pathways, enabling a more coherent arbitration among behaviours. Behavioural fatigue, among other temporal mechanisms, has been introduced in order to avoid dead-lock situations. These ideas have been extended with fuzzy logic, enabling a richer semantics, and production of sensorimotor topological maps. In a latter development, a constraints-based behavioural architecture has been proposed. The underlying idea is that behaviours should be able to cast constraints on the action actually being engaged on the robot's actuators, which is of particular interest for the arbitration of safety-related behaviours.

Another source of behavioural richness is teamwork, in particular the one that involves humans. In this sense, we have also contributed to the human-robot interaction problem, by proposing a knowledge-based multi-agent system to support design and execution of stereotyped tasks under the teamwork concept. The novel application of cooperative workflows for the task at hand enabled tightly coupled interactions among team members. Rather than focusing on automatic teamwork planning, the proposed model offers a complementary and intuitive knowledge-based solution for fast deployment and adaptation of small scale human-robot teams. In addition, the system has been designed in order to provide humans with overall mission awareness, which is essential for field robots operating in demanding environments.

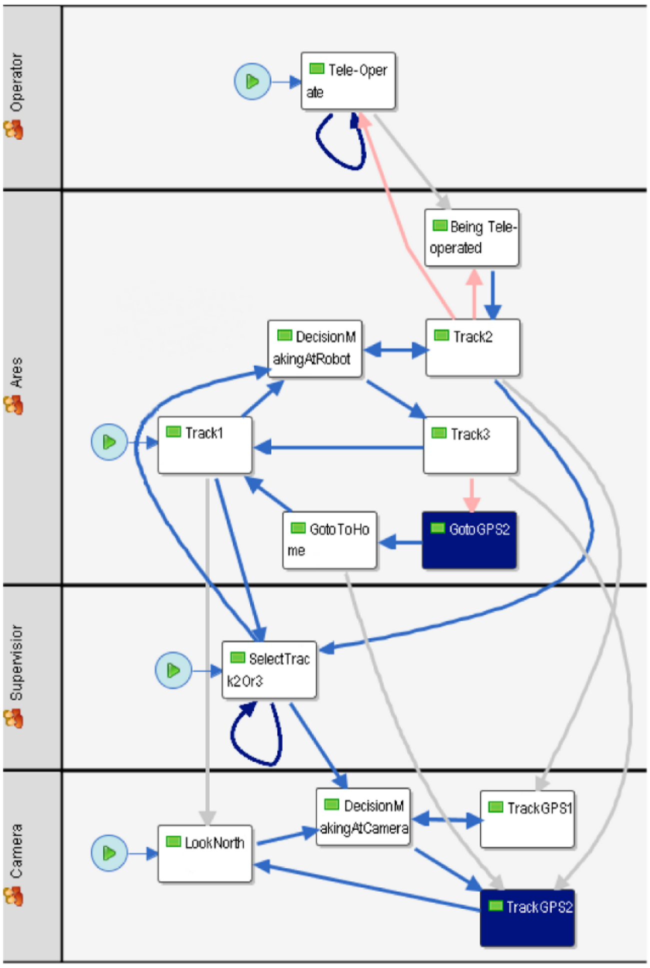

Fig. 4 – Example of a cooperative workflow describing the work of a team composed of a robot, an operator, a mission supervisor and an autonomous tele-operation camera mounted on the robot. Each box represents an activity and links represent conditional transitions and data links among activities.