The Sensing Subsystem of RAS

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The RAS, “Robot Antartico di Superficie”, is intended to operate in a hostile and generally unknown environment, where the ability of sensing obstacles or special features (crevasses, sastrugi, composition of the soil) can represent the key point to successfully perform the required mission or to fail: wind storms (and many other atmospheric phenomena giving rise to white out) can make useless optical sensing equipment; ice microcrystals can penetrate practically everywhere, causing failures in many components; magnetic storms can blind GPS and radio equipment.

Thus, during the architectural phase of the RAS design, it has been stated that one of the basic features of the sensing subsystem of the robot should be the “environmental hardening” and another the “redundancy”. The last mandatory choice, indeed quite expensive, has caused the creation of an extremely rich sensing unit, able to investigate the outside environment with many “eyes” and in many ways.
The sensing architecture of RAS includes the following units:

- ✓ Two laser range finders (LRF), able to scan an angle of 120° in front of the vehicle;
- ✓ A radar range finder, to integrate the data coming from the LRF or to act as a emergency backup system when the weather doesn’t allow the LRF operation;
- ✓ An odometric subsystem, able to estimate the speed of the tracks from the maximum speed of the carrier down to about 3 cm/sec with accurate filters;
- ✓ A very sensitive inertial equipment, for the measurement of the X-Y-Z accelerations, of the two rotations and inclinations along the X and Y axes;
- ✓ An artificial vision subsystem, based on a stereo pair of TV cameras that can be operating on visible or infrared range of optical light spectrum. The system will be charged with several tasks, but currently able to track the position of other vehicles on the scene and to follow the traces left from the previous vehicle (in a caravan);
- ✓ A differential, RTK GPS system, able to give centimetre precision during the movement for several purposes (control, record of special positions, execution of precision positioning works, docking, etc…)
- ✓ A “speed over ground” optical sensor, entirely developed at ENEA and defined “Speckle Velocimeter”. It has demonstrated to reach in the best conditions precisions close to 0.1% in the simultaneous measurement of X and Y components also on a contrast lacking surface as the snow;
- ✓ A GPR (Ground Penetrating Radar) equipment, specialised for the detection of the soil structure in the first ten meters in depth and therefore especially able to detect crevasses, surface lakes, but also small surface or low depth meteorites.

Additional cameras are foreseen to integrate the previously sensing equipment for a more effective teleoperation (the stereo pair has some limitations in the viewing area because the rear and lateral part of the vehicle are hidden by the cockpit structure), but aren’t yet installed. A weather monitoring box is also foreseen to allow the best data fusion coming from the many sensing units, but not yet implemented.
The whole sensing system is represented in fig. 1.

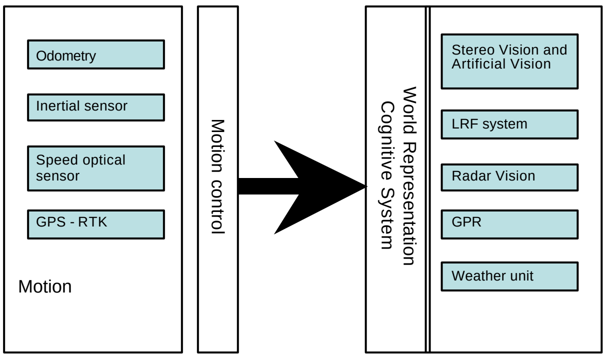

Fig. 1 – simplified sensing architecture of RAS

The complex aspects of the integration and utilisation of data coming from the different sensors will not be discussed in this paper. In order to give an idea of the work carried out during the PNRA project on the Robot for Antarctica Surface three sensors developed inside the project will be presented in some detail: the LRF, the Artificial Vision and the Speckle Velocimeter

Laser Range Finder

This sensor has been designed and realised using an original ENEA technology with the following specifications, as reported in the original document of RAS project:

- Range of measurement: 50 m.
- Precision: 5 cm
- Point measurement time: 1ms
- Opening angle of the scanning system 60°

For practical reasons, such as the need to limit the scanning time at fixed angular resolution, it has been accepted a design limitation of the opening angle to a maximum of 48°.

All the other features of the system have been proved to maintain the specifications in Antarctica environment (in fig. 2 a phase of the tests carried out in the proximity of the Italian base of Baia Terranova) under an extremely high solar radiation intensity. Exploitable signals have been measured in these conditions up to 100 m.

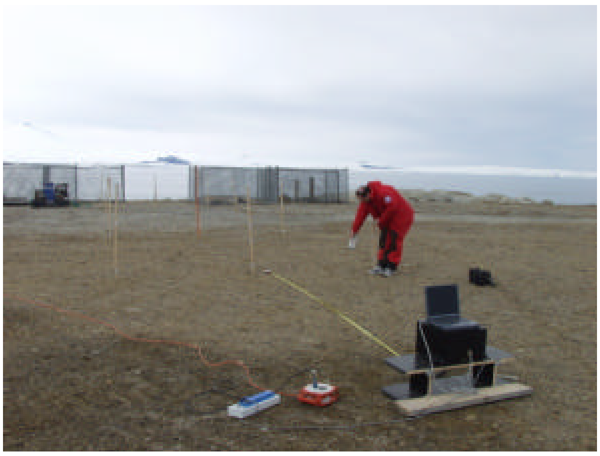

Fig. 2 – Laser calibration in a field in the nearby of the Baia Terranova base

Fig. 3 – Laser tests on the snow

Laser sensors are now widely diffused on the market, but the ENEA's technology is till now on the edge with special reference to sensitivity, precision and speed. In particular the device realised for RAS (in fig 3), has peculiar features in terms of ruggedization against the environment and speed of operation and can be configured to increase precision or scanning speed depending on the most important need relevant to the navigation. A pair of LRF, placed in front of the RAS vehicle are able to cover all the visible area with reaction time as low as ½sec.

Artificial Vision system

The artificial vision represent one the main sensors of RAS. It is based on a stereo camera pair and has the task to support the drive of the vehicle in the following conditions: traverse operation (see sketch in the following), docking, scouting in dangerous conditions.

The functions introduced up to now are relevant to the tracking of the preceding vehicles. Several advanced algorithms have been set up and tested for a comparative analysis of the performances. Among the other the most promising ones have been based on the weighted Hough transform (see fig 4. and fig. 5. for schematics and results) and on the algorithm of Ant Colony Optimisation (ACO – see fig. 6 for some results).

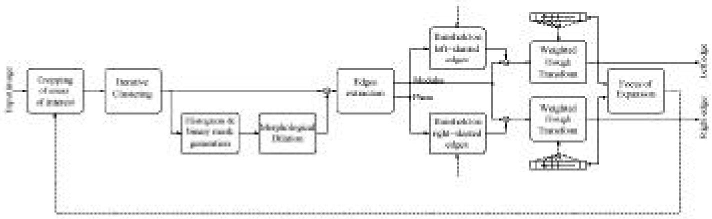

Fig. 4 - Block diagram of the processing for the weighted Hough transform.

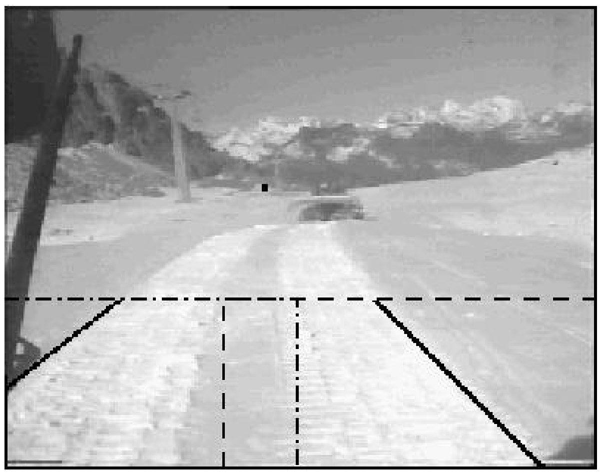

Fig. 5 – Result of Hough transform processing

The next progresses foreseen in the AV subsystem are related to the exploitation of IR cameras. Their exploitation is expected to be especially useful for detection of breaks in the ice coverage (including crevasses and borders of floating marine ices) and should be carried out within next "RUISS" project.

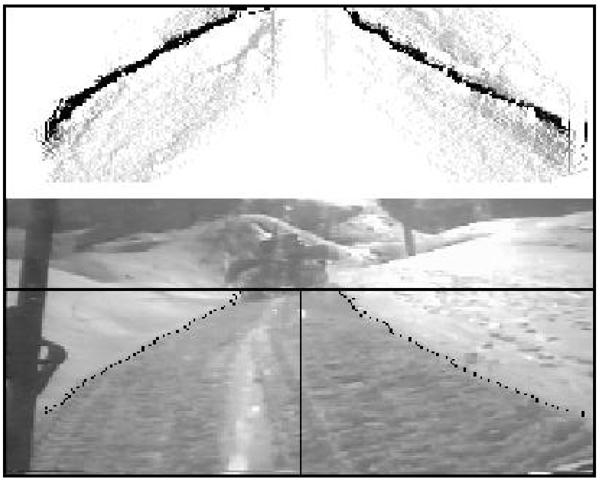

Fig. 6 – Examples of the best path selected by the ants; the upper part of each image encodes the number of ants passed on each pixel.

Speckle Velocimeter

Speckle Velocimeter is based on the classical idea of the speed calculation of two relative moving objects starting from regular or semi-regular terrain textures and developed with the idea of apply a laser-induced speckle pattern to surfaces texture-free like the snow is (see fig. 7).

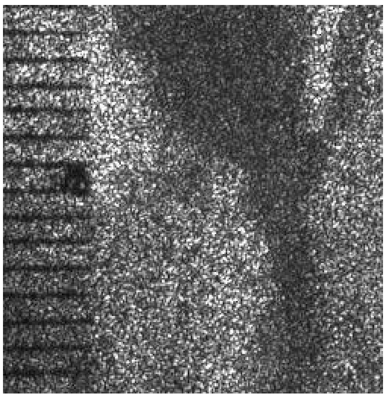

Fig. 7 – Speckle photograph. Resolution 512x512 pixels. The vertical scale division is 1 mm.

This pattern, under non critical optical conditions, has the property to translate rigidly with the lightened surface, thus allowing the calculation of a true optical flow. Another key point is that the application requires a flow calculation method featured with the very high measurement precision.

The basic idea was to develop a sensor able to achieve precision of the order of 0.1% in the velocity measurement, with simultaneous detection of X, Y and rotation components, featured with a repetition rate in the order of ten measures per second. During the state of the art analysis phase several possible solutions have been investigated including the Doppler Interferometer (commercial prototypes exist giving high speed and precision, but with critical field depth characteristics) and doppler microwave radar (whose limits are currently under investigation).

The initial requests have been successfully reached for the simultaneous measurement of X and Y components. Rotation components have been proved impossible to measure with the current resolution of fast cameras and using a single viewpoint but, on the other hand, the sensitivity of the inertial system already installed on RAS is fully adequate for a quick and precise driving system.

The exploited algorithm make use of a Radon Tranformation, a general transform function (not local as the Hough one) that is able to give a very high precision. In the next picture (fig. 8) we can see the result of a plot speed vs angle exploited throught the use of Radon transform to the time-resolved flow of images captured through a standard PAL camera.

Application to the real case is still to carry on because this algorithm demands for considerable computational power and for a very fast CCD equipment. The equipment (based on biprocessor XEON 2.8 Ghz and a DALSA 1000 fps CCD) has been already purchased, the software is under adaptation and the field tests on the snow should be accomplished during a campaign scheduled on november 2003.

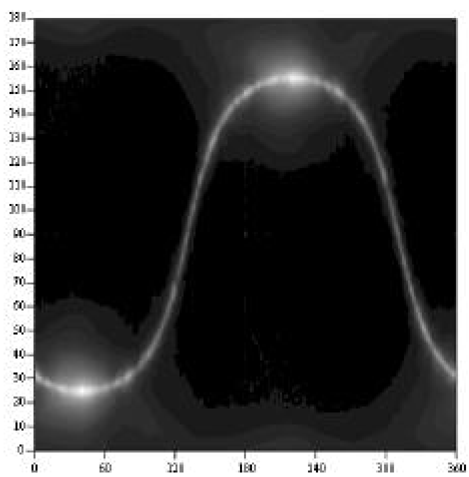

Fig. 8 – Speed vs Angle plot for a laboratory experimental test of the Speckle Velocimeter

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