KINEMATIC GNSS SURVEY: EXPERIENCES TO BE TRANSFERRED

Caroti G.[1], Cefalo R.[2], Manzoni G.[2], Palla B.[1], Skerl G.[1]

[1]Institut of Geodesy, Topography and Photogrammetry, University of Pisa, V. Filippo Buonarroti 1, I-56100 Pisa, Italy
[2]Department of Civil Engineering, Section of Road, Transport and Topography,
University of Trieste, P.le Europa 1, I-34127 Trieste, Italy

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ABSTRACT

The GNSS, Global Navigation Satellite System, as an integration of GPS (Global Positioning System, USA) with GLONASS (GLObal NAvigation Satellite System, Russia), is a powerful tool for survey and navigation. The University of Trieste, with the cooperation of the University of Pisa, has tested the GPS and GNSS in a number of environments, ranging from the urban canyons to the mountain glaciers (Olivier R., Rosselli A., and others 1996), both for cartography and road GIS, as well as for geophysical prospecting. Results show that this tool could be usefully transferred in the frame of international cooperation.

Introduction

GNSS means Global Navigation Satellite System; at present, it is GPS+GLONASS; in the future, several other satellites could be added, geostationary ones in particular. Since the instrumental technology is either American or Russian, the transfer of technology from Italy can be mainly in field experience.

In this paper, we will mention the following items, which can be transferred on the basis of our experience:

- GPS/DR Urban Navigation
- GPS/DR Applications in Environmental Monitoring
- Road Survey by means of Kinematic GPS+LASER

2. GPS and GLONASS

The integration of the two major satellite navigation and positioning systems, GPS (Global Positioning System, USA) and GLONASS (Global Navigation Satellite System, Russia), means up to about 13 satellites available above the horizon for coordinate determination everywhere and all time.

Since GLONASS is not affected by strategic data errors, known as Selective Availability (SA), then a stand alone receiver allows an instantaneous undifferenced positioning with about 10 meters accuracy. This is fairly better than the GPS stand alone accuracy of 100 meters or more.

Nevertheless, since the latter can be reduced to a few meters with several hours of steady observations, both GPS and GLONASS, as well as their combination, can be used for general cartography purposes, or general navigation operations, by a single operator.

In all the other cases, where a better accuracy is required, other techniques must be used, involving two or more instruments working simultaneously: post processing and real time Differential GPS or, when interferential measurements are available, post processing and real time precise positioning by means of double difference algorithms.

The following table compares the GPS and GLONASS parameters:

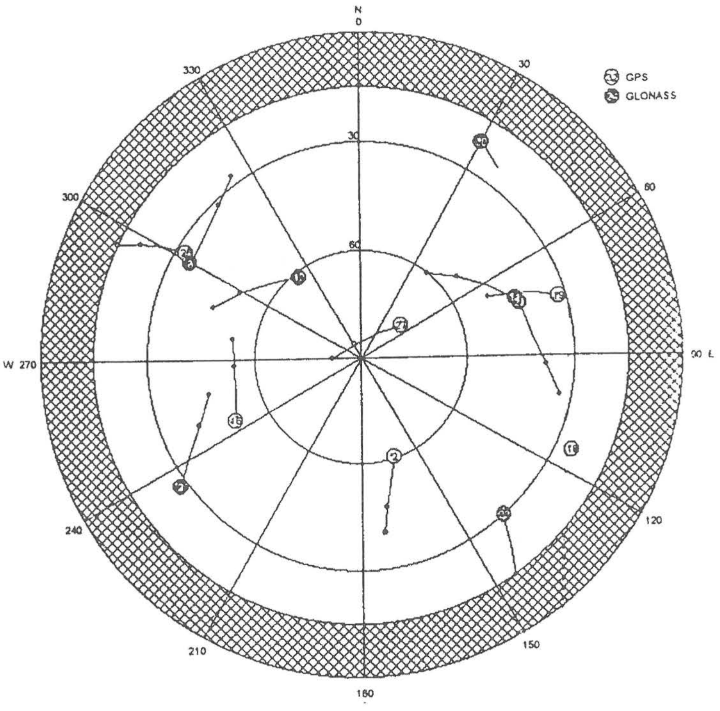

fig.1 A GPS&GLONASS typical sky plot

TABLE 1 Comparison between GPS and GLONASS parameters

CHARACTERISTIC	GPS	GLONASS
Carriers frequency	L1 1575.42 MHz	L1 1602+K·0.5625 MHz
	L2 1227.60 Mhz	L2 1246+K·0.4375 Mhz
Frequency of C/A signal	1.023 Mhz	0.511 Mhz
Strategic data errors SA	Yes	No
Frequency of P signal	10.23 Mhz	5.11 Mhz
Criptation of P signal	Yes	No
Number of final satellites	24	24
Number of orbital planes	6	3
Number of satellites per orbit	4	8
Orbit inclination	55°	64.8°
Orbital radius	26560 km	25510 km
Orbital period	11h58'	11h15'
Geodetic Reference System	WGS84	PE-90 (SGS90)

WGS84 = World Geodetic Datum; 1984 SGS90 = Soviet Global System 1990
K = identification number of the satellite

The GNSS can be used in different ways, according to the required accuracy and mode of survey (static or kinematic). Depending on the GPS receivers' architecture, it is possible to measure the pseudoranges (C/A code) or the carrier phase (only L1 or L1/L2) only; in the stand alone mode, C/A code only can be used (absolute positioning). When using two or more receivers simultaneously, one can have static and kinematic DGPS (C/A measurements only), or interferential (geodetic) GPS, static or kinematic too; in the latter case, a static initialisation is needed in order to determine the ambiguity of the carriers. Several operational modes are available: static, fast static, continuos kinematic, stop and go, real time kinematic with OTF (On The Fly) algorithm for quick computation of ambiguities.

For all these modes, we tested the accuracies in coordinate determination in several operational situations and different environments,; a synthesis of the obtainable results are reported in the following table:

TABLE 2 Experimented accuracies in various GPS and GLONASS configurations

MODE	**instantaneous**	**static**
Stand alone GPS C/A (pseudorange)	15 m without SA 150 m with SA	8-12 m under particular conditions (8-24 hours of registration)
Differential C/A (DGPS) Real Time	5 m radio connection required (RTCM-SC104)	
DGPS post-processing	2-5 m	1 m in 1 hour
Differential GPS submeter	0.8 m (like above)	0.2 m in 1 hour
Interferential GPS (carrier phase and double differences) L1		5 mm in 1 hour up to 1 km 5 mm up to 10-15 km (more hours)
Geodetic static GPS (carrier phase and double differences) L1/L2		10 mm+1 mm/km
GPS fast static L1/L2		10 mm in 8 minutes
GPS continuos kinematic	5 cm initialisation required	
GPS real time kinematic L1/L2 with OTF (radio connection required)	5 cm in 2' initialisation	1 cm in 2' initialisation
GLONASS stand alone	8 m	
GNSS	7 m	
DGPS + GLONASS	0.5 m	
DGPS + DGLONASS	0.5 m	

All the computational procedures involved in the different GPS modes are well known. We report here one only, which is the analysis of the RDOP parameter essential for a correct use of the kinematic method: the analysis of accuracy plays a fundamental role in all these applications, because of its influence on the final quality of the survey. Some parameters are commonly used for the evaluation of accuracy in GPS measurements, like PDOP (Position Dilution of Precision) and RDOP (Relative Dilution of Precision). These parameters give an idea of how the spatial configuration of satellites affects the accuracy of the point coordinates; for this reason it is very important to evaluate an "a priori" PDOP or RDOP for the survey period, in order to avoid a bad quality survey (e.g.: float solution for ambiguity computation, high RDOP with consequence of low accuracy in a continuous kinematic survey or termination in an RTK survey, etc.).

The GPS+GLONASS method has been tested in the past few months by means of an Ashtec GG24 receiver (Manzoni, 1996), which was initially kindly loaned by Codevintec Italiana: the results of such experiments are reported hereafter; in all the cases, the data have been recorded every 1 second.

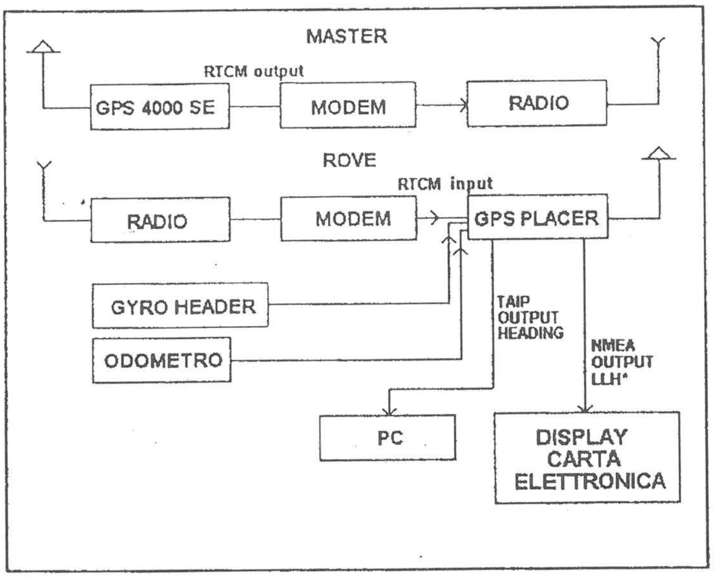

fig. 2 scheme of a low cost GPS/DR

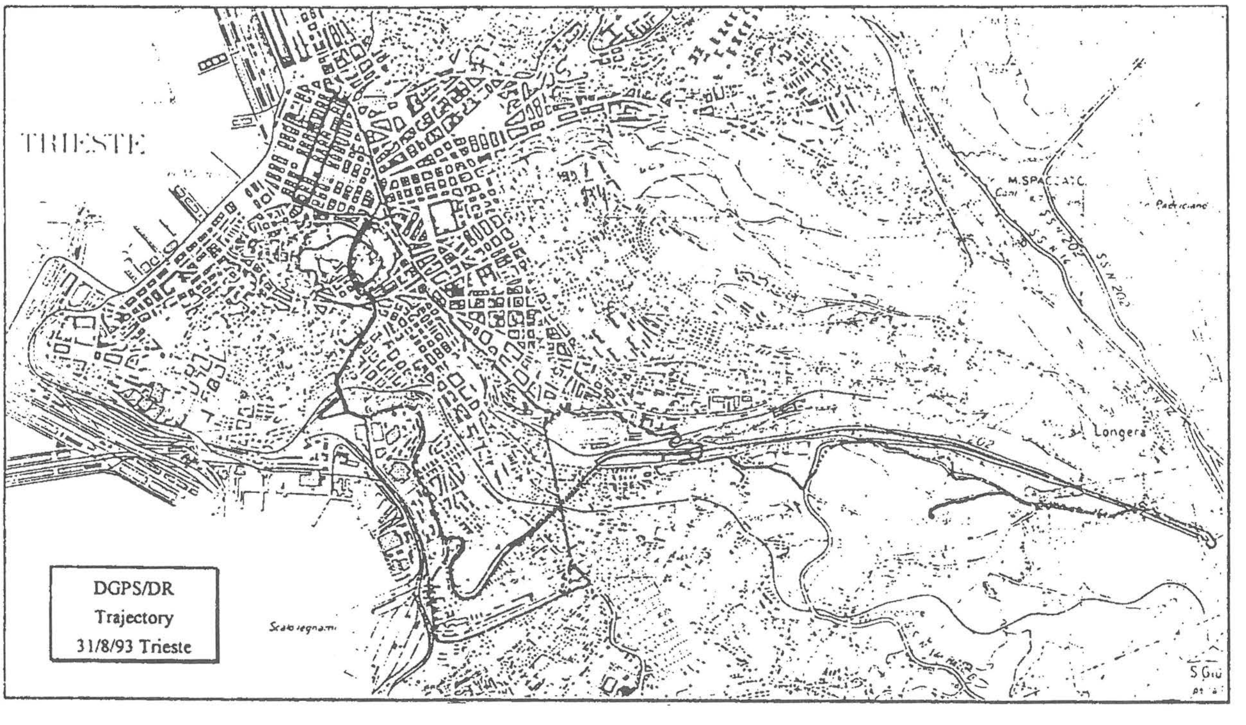

fig.3 DGPS/DR real time navigation in the city of Trieste

Static Pseudorange

GPS+GLONASS on a roof with complete visibility of the satellite constellation as well as limited multipath noise: during a 12 hours observation, a standard deviation of 3 meters horizontally and 10 meters vertically was obtained;

GPS+GLONASS between buildings, with limited visibility of the sky and high multipath noise: in 4 hours, a standard deviation of 13 meters horizontally and 26 meters vertically;

DGPS+GLONASS between buildings, 2 sat DGPS+6 GLONASS, in about 1 hour and 20 minutes, gave a standard deviation of 1.5 meters horizontally and 16 meters vertically;

DGPS+DGLONASS on the roof, in about 5000 seconds, gave a standard deviation of 12 centimeters horizontally and 24 centimeters vertically.

Kinematic Pseudorange

Non Differential

A vehicle equipped with a GG24 receiver drove from Trieste to Venice back and forth the highway, forward in the morning and backwards in the afternoon. The trajectories resulted well separated and in the right position in the driving direction.

Differential

An experiment in Milan was performed in DGPS+DGLONASS, obtaining quite well overlapped trajectories in two subsequent runs.

In several situations, GNSS is aided by INS (Inertial Navigation System); this allows the navigation under trees and in cities without any interruption in trajectory registration.

An accurate INS, based on three gyroscopes and three accelerometers, is generally very expensive and subject to restrictions due to its strategic uses.

Anyway, low cost INS (2000 $ or less, GPS included), based on a solid state gyro and wheel rotation counter (odometer), can be a sufficient dead reckoning (DR) support to GNSS. Urban navigation and survey have shown to be feasible with 10 meters accuracy associated with DGPS. Experiences with GPS+GLONASS are in progress.

Many experiments were led at our Universities with a system called Placer/DR, also coupled with environmental sensors for instantaneous mapping of pollution (Camus et al., 1995; Cefalo P., 1996). This application of GPS positioning can be easily transferred and may represent the major added value to GPS presented by the Pisa-Trieste groups.

Another added value to the GPS method is the differential phase, plus Laser integration: it was used for precise road survey (Manzoni M., Peressi G.; Zini M., this issue).

3. Conclusion

The above mentioned experiments are a high added value to GPS applications. Therefore, they are feasible for technology transferring, even if they do not regard the GPS itself. We think that the applications of the GPS and GLONASS method is the goal of the international cooperation.

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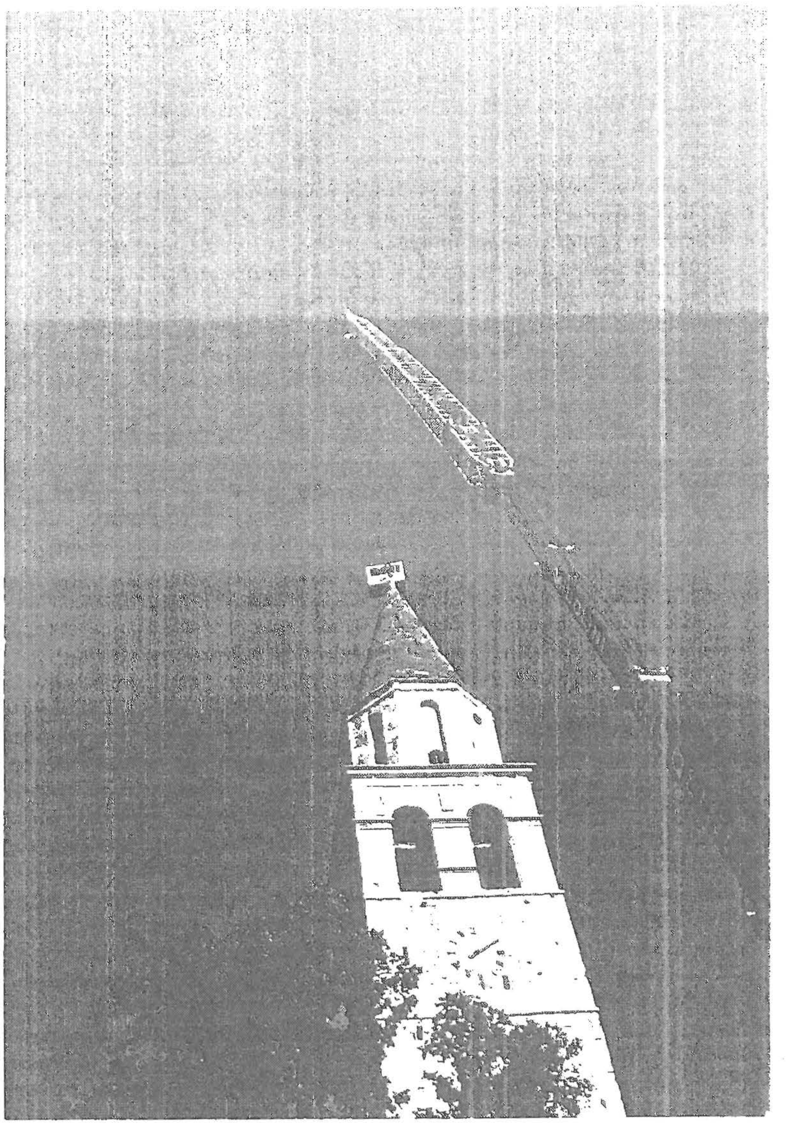

fig. 4 Cartographic survey with GPS positioned on a National IGM point of known geographical coordinates (Aquileia).

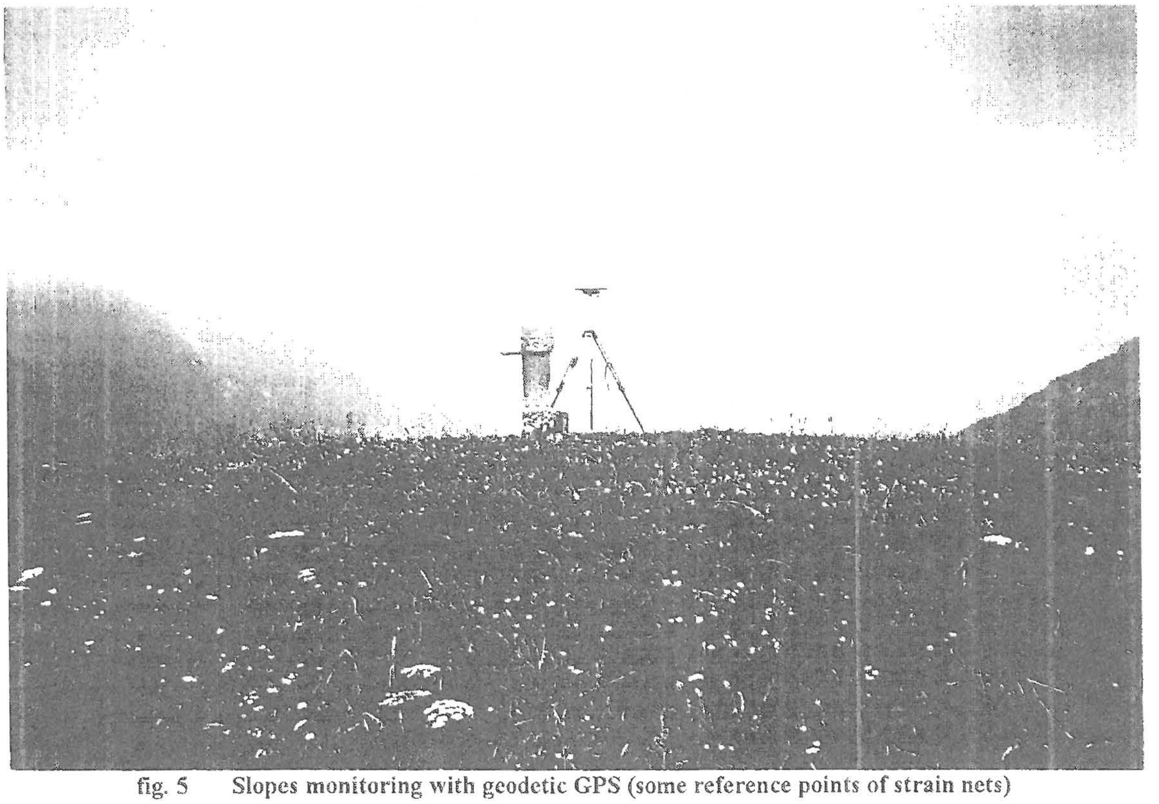

fig. 5 Slopes monitoring with geodetic GPS (some reference points of strain nets)

fig.6 Geophisical survey in alpine glaciers using geodetic static and kinematic GPS (cooperation with University of Milano, University of Lausanne and Autonomous Province of Trento)

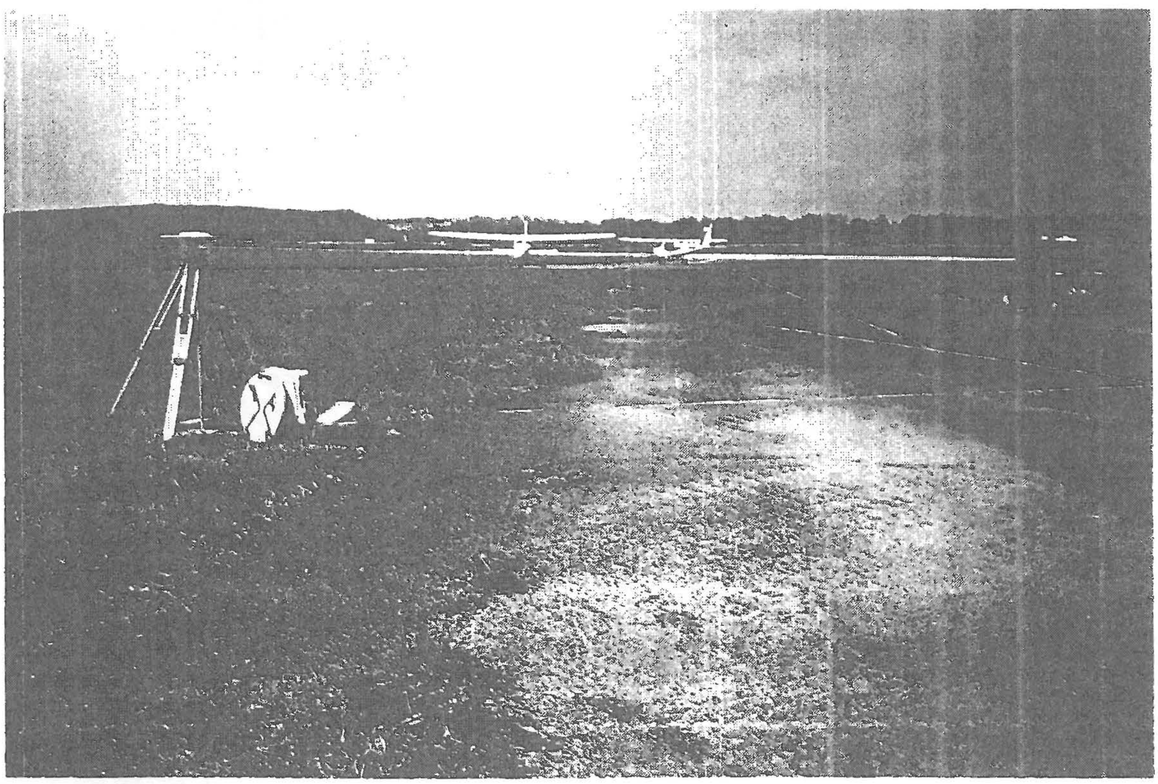

fig. 7 Airplane positioning and airport georeferentiation (cooperation with various italian organizations)

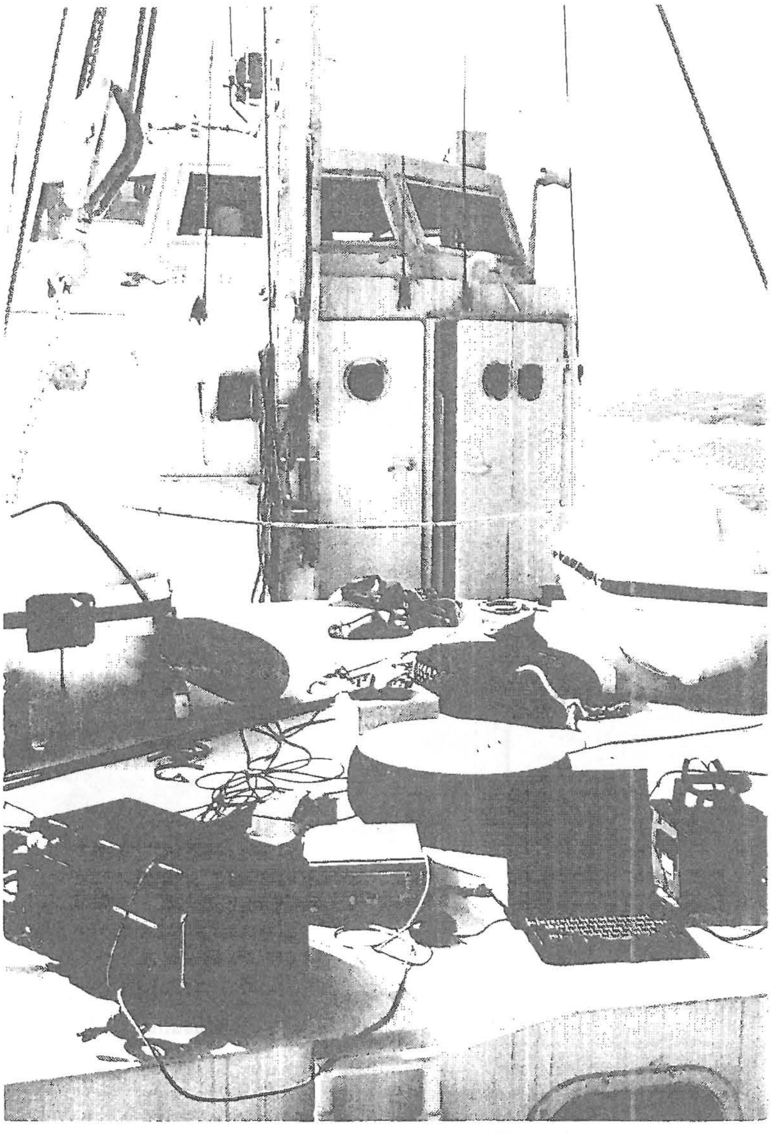

fig. 8 Monitoring and mapping of marine pollution (GPS and electrochemical sensor) in cooperation with Istituto Tecnico Nautico of Trieste

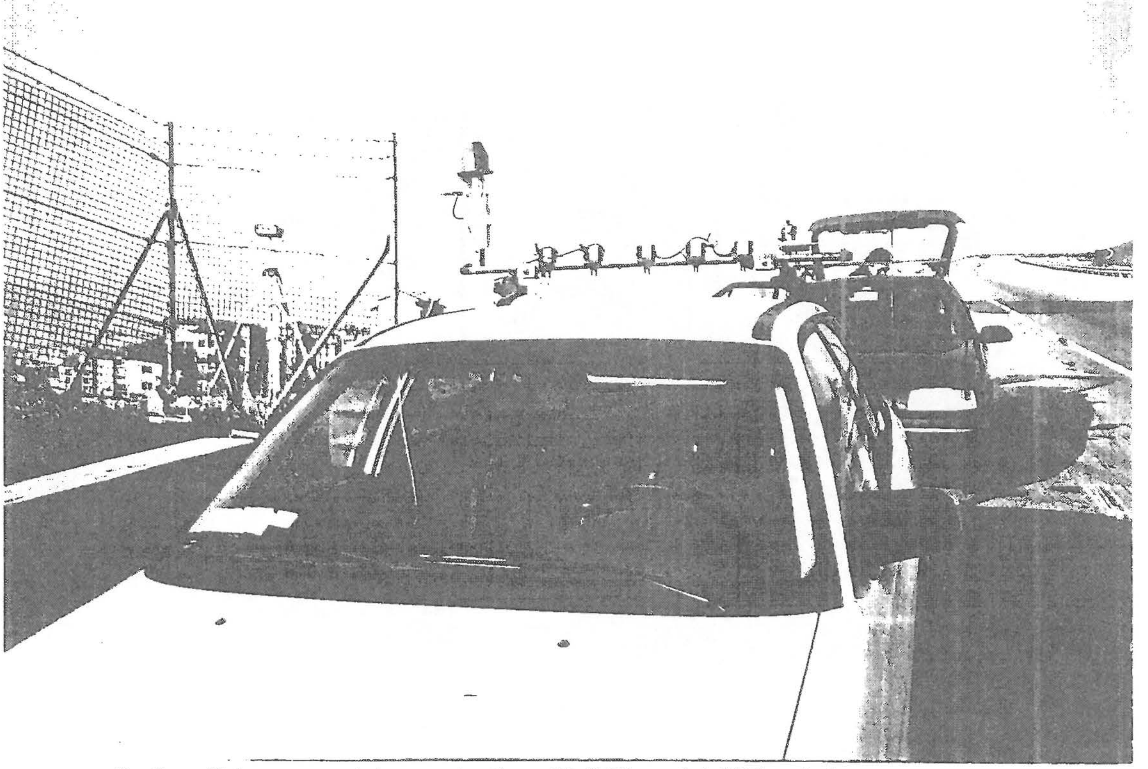

fig. 9 Urban car real time navigation with Differential GPS techniques