A GENERAL PURPOSE POSITIONING SYSTEM FOR CONSTRUCTION ROBOTICS

Jean-Luc Salagnac, Head of the Robotics and Construction Division
Centre Scientifique et Technique du Bâtiment (CSTB)

Etablissement de Sophia Antipolis
BP 21
F 06561 VALBONNE CEDEX
FRANCE

ABSTRACT

Mobility has been early identified as a key function for future construction robots.It is then essential to develop navigation modules, pilot modules and positioning modules that fit with the constraints of the work site.Concerning the positioning modules (that provides coordinates and orientation of the mobile robot related to a fixed coordinate system), we think that cost attractive and reliable systems must be developed taking into account the peculiarities of construction techniques and methods. This means in particular that the positioning systems to be developed will use either existing measuring devices or different kinds of beacons included in the construction design.This paper presents a patented system belonging to the first class of solutions. The system consists of a rotating laser transmitter installed at a fixed point of the work site. The mobile robot is equiped with suitable sensors providing geometrical informations which are processed in real time by a computer carried by the mobile robot. The basic principle of this system is described in this paper as well as the experimental developments. Examples of applications of this system are given.

1. INTRODUCTION

Most the existing experimental construction robots developed in industrialized countries during the last years are mobile robots.

Such a supremacy clearly appears through the proceedings of the five first issues of the ISRC ([1] to [5]). This results obviously from the fact that mobility is a basic function to be fulfilled on construction sites.

This function can be split in three parts according to figure 1.

The pilot and the navigator constantly need to be informed of the exact position of the robot.

This crucial need requires suitable positioning systems that fit to the constraints of the construction site.

The systems which are developed in laboratories too meet the requirements of the movements of mobile robots in unstructured

environments are certainly nowaday too sophisticated for construction applications (stereo or dynamic vision, for instance).

The systems which have been developed for industrial purposes are difficult to use on construction sites because the structure of the site changes constantly (wire guiding, fixed passive beacons, for instance).

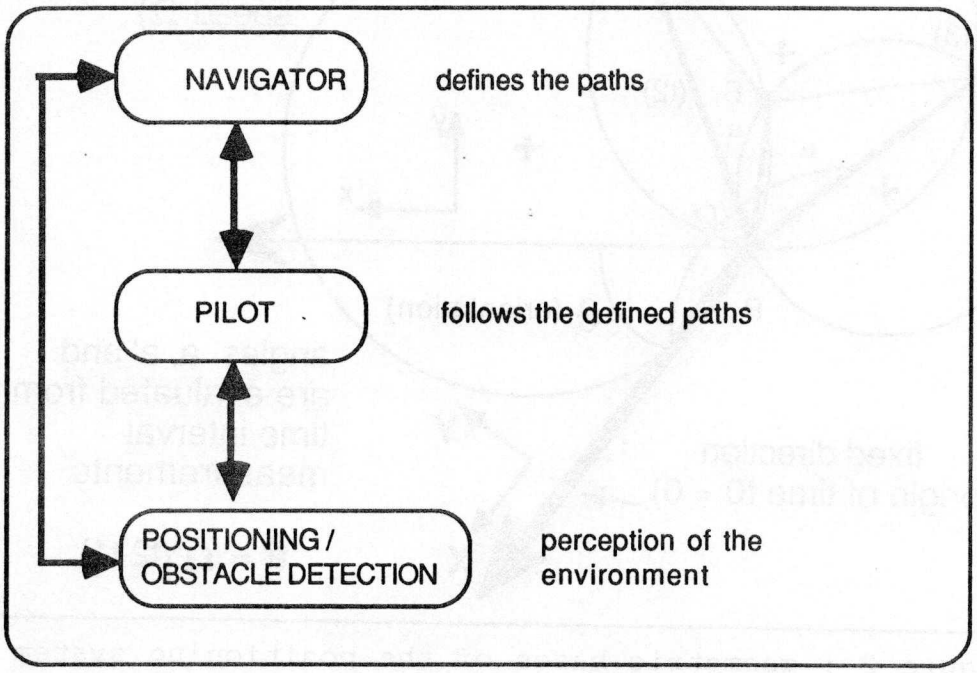

Figure 1 : The three steps of the mobility function

We then plead for intermediate solutions which take advantage of both the evoluting structure of the construction site and of existing measurement devices used on sites.

The proposed system uses a rotating laser transmitter which is nowaday commonly used during the construction phases (for both outdoor and indoor tasks).

Many positioning systems using one or more laser transmitter have already been developed ([6] to [9]), but the originality of the proposed system (which has been patented) comes from the fact it is very easy to use and from its great potential of applications.

2. BASIC PRINCIPLE

Figure 2 shows the geometric bases of the positioning system.

The positions of points A, B and C are known refering the x,y coordinate system.

The measurements of two angles (a and a') allow to determine the coordinates of point P refering to the x,y coordinate system.

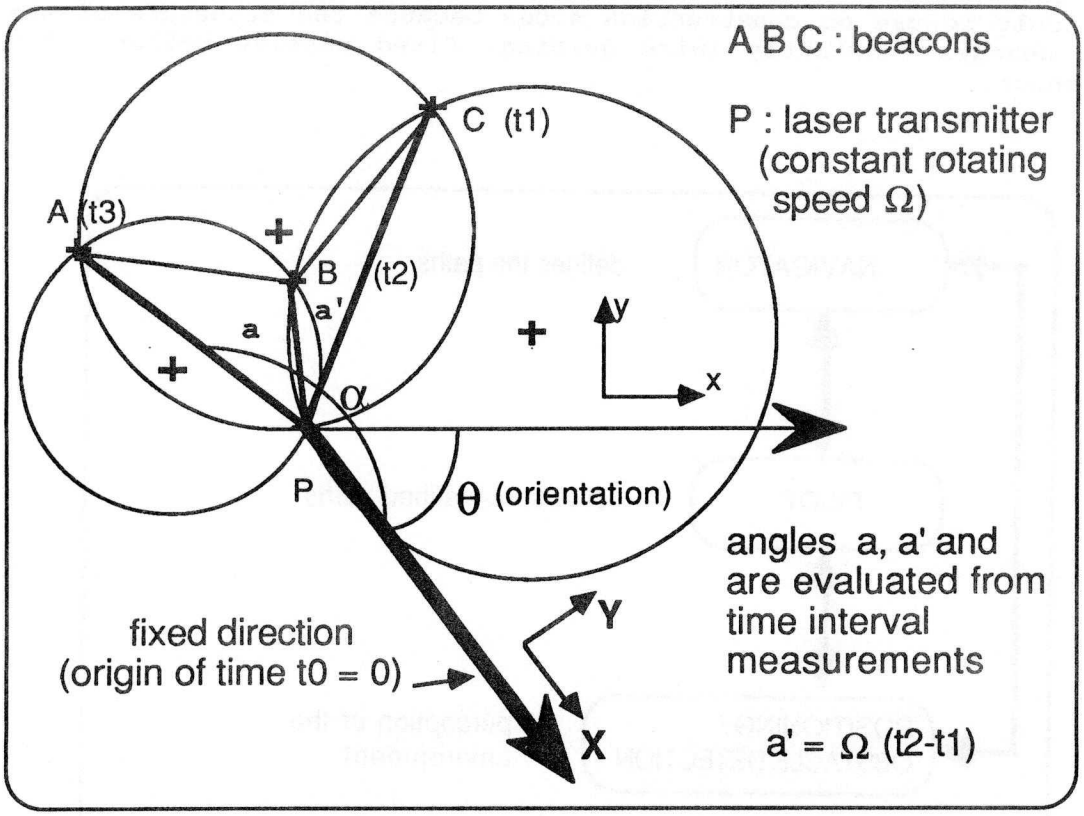

Figure 2 : geometric bases of the positioning system (evaluation of the position and of the orientation in the laser plane)

PX is a fixed direction.

It is then obvious to calculate the coordinates of say, point A, refering to the X Y coordinate system as soon as the angle α between PX and PA (as far as point A is considered) is known.

The orientation θ is then evaluated.

The rotating laser transmitter is at point P. The rotation speed is constant. A, B and C are beacons linked to the mobile robot. When a beacon is touched by the laser beam, a timer is read. The angles a, a' and θ are evaluated from time interval measurements. The timer is reset at each rotation when the laser beam is in the PX direction.

The position of any point of the robot and its orientation can theoretically be evaluated once per rotation. Note the points A, B and C can be aligned or not.

The position evaluation described above is only valid when the points A, B and C are in the laser plane. If not so, it is possible to design rod-like beacons so as to measure the heights of the laser beam on each beacon. The position, orientation and tilt angle of the robot can then be evaluated (in this case, points A, B and C must not be aligned) (see figure 3).

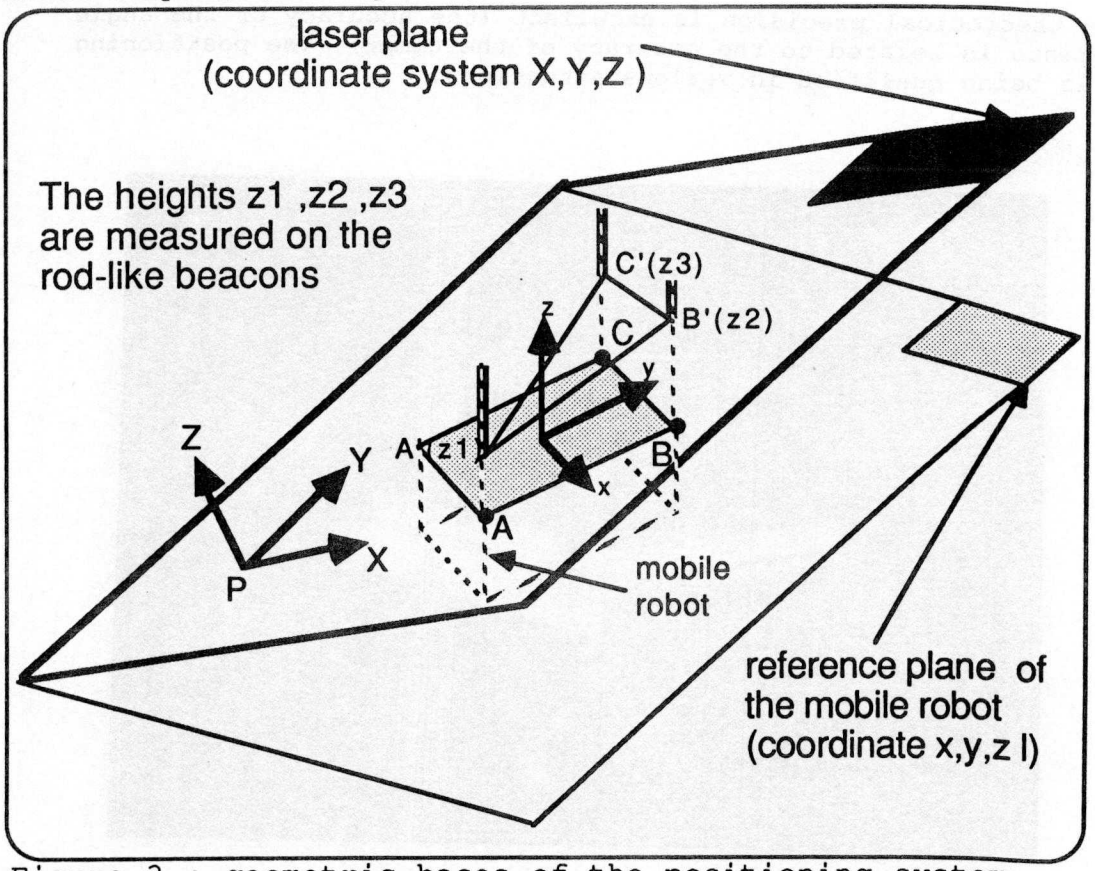

Figure 3 : geometric bases of the positioning system (evaluation of the position ,the orientation and of the tilt angle between the laser plane and a plane linked to the mobile robot)

3. EXPERIMENTAL DEVELOPMENTS

Hardware and software necessary to have an experimental positioning system based on the presented principle have been developed in the Laboratory of Robotics of the CSTB.

Figure 4 shows a picture of the experimental equipment.

The mobile platform is a Robuter (commercialized by ROBOSOFT), the laser transmitter is a Magiplan (commercialized by R.P.M.). The beacons are photovoltaïc cells. Interface hardware has been developed between the beacon signals and standard 68XXX family processing card. The programable timers of the CPU have been used to measure time intervals.

The software has been written in C language. Under experimental conditions, the rotating speed is 10r.p.s. The measurements are made every two revolutions so that a complete position is given every 0.2 s.

The theoretical precision is excellent (the accuracy of the angle measurements is related to the accuracy of the timer). The positioning system is being qualified in various situations.

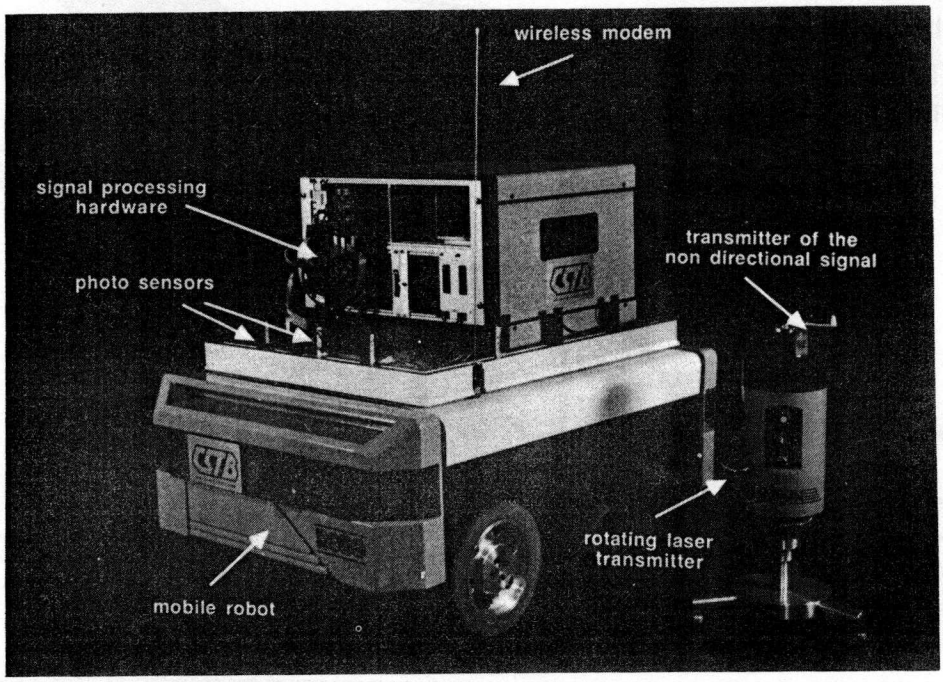

Figure 4 : view of the experimental equipment

4. APPLICATIONS

The need of a positioning system is of course crucial for mobile robots (for indoor tasks or outdoor tasks on building construction sites or for road construction sites, for instance).

Many other applications can be imagined which are not necessarily related to mobile robots.

Figure 5 shows some of these applications on construction sites.

The position control of a tool (a concrete form on figure 5b) can be facilitated by the use of the proposed system.

The laser plane can be vertical (or tilted) so as to make it possible to measure the position of a (moving) tool on a vertical (or tilted) surface.

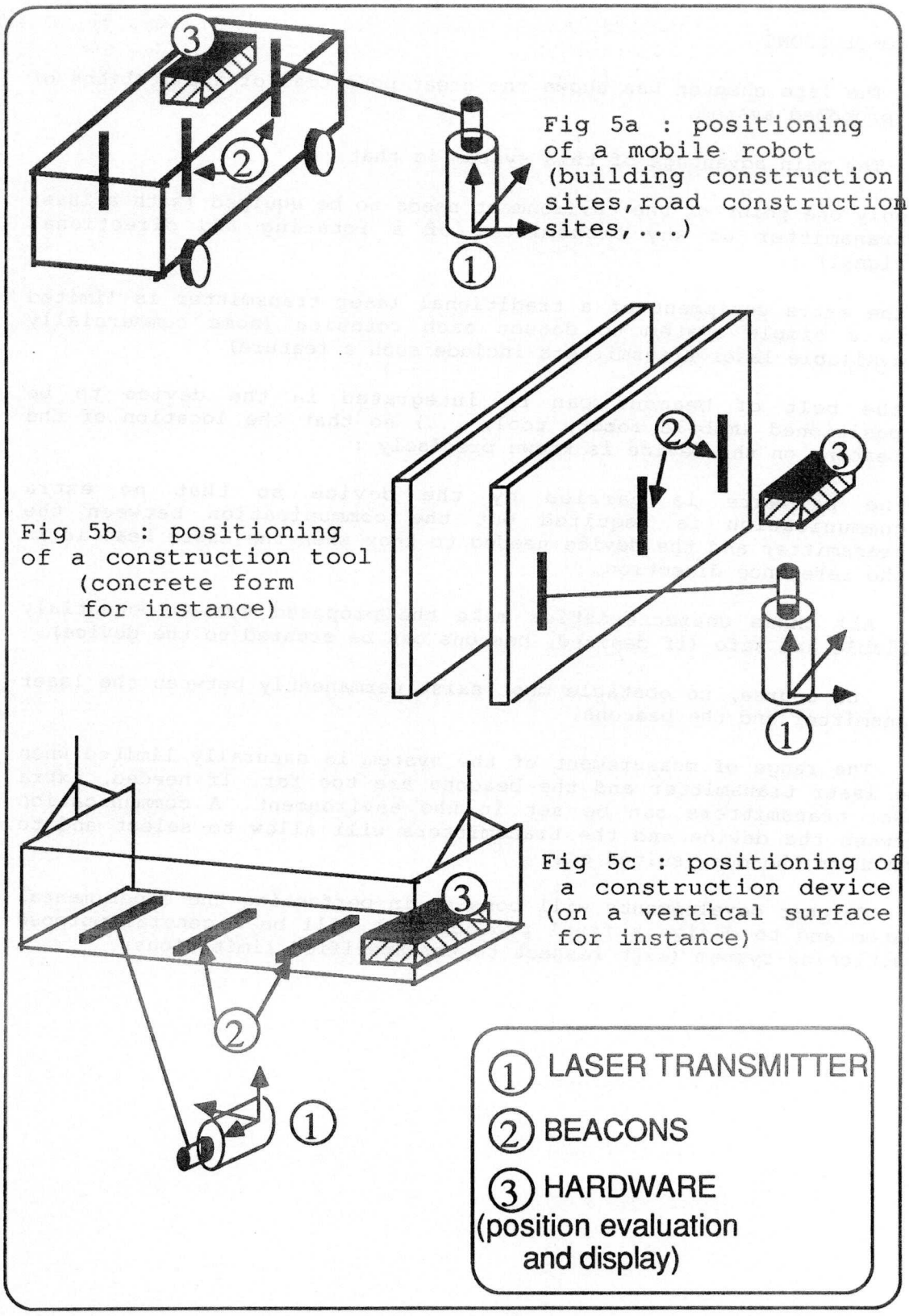

Figure 5 : some applications of the positioning system

5. CONCLUSIONS

The late chapter has shown the great potential of applications of the proposed system.

The main advantage of this system is that :

- only one point of the environment needs to be equiped (with a laser transmitter or any transmitter of a rotating and directional signal) ;

- the extra equipment of a traditional laser transmitter is limited to a simple system to detect each rotation (some commercially available laser transmitters include such a feature) ;

- the belt of beacons can be integrated in the device to be positioned (mobile robot, tool, ...) so that the location of the beacons on the device is known precisely ;

- the hardware is carried by the device so that no extra communication is required but the communication between the transmitter and the device needed to know when the laser beam is in the reference direction.

All these characteristics make the proposed system potentialy reliable and safe (if desired, beacons can be secured to the device).

Of course, no obstacle must exist permanently between the laser transmitter and the beacons.

The range of measurement of the system is naturally limited when the laser transmitter and the beacons are too far. If needed, extra laser transmitters can be set in the environment. A communication between the device and the transmitters will allow to select and to switch on the most suited one.

Further developments will consist in perfecting the experimental system and to design a final product that will be a general purpose positioning system (with respect to the specified limitations).

BIBLIOGRAPHY

[1] Proceedings of the Workshop Conference on Robotics in Construction, CMU, Pittsburgh, 17-20 june 1984.-Pittsburgh, CMU, 1984

[2] Proceedings of the second Conference on Robotics in Construction, CMU, Pittsburgh, 24-26 june 1985.- Pittsburgh, CMU, 1985

[3] Proceedings of the Conference CAO et Robotique en Architecture et BTP, CSTB, IIRIAM, GAMSAU, Marseille, 25-27 june 1986.- Paris, HERMES, 1986

[4] Proceedings of the Fourth International Symposium on Robotics and Artificial Intelligence in Building Construction, TECHNION, Haïfa, 22-25 june 1987.- Haïfa, TECHNION,1987

[5] Proceedings of the Fith International Symposium on Robotics in Construction, JIRA, Tokyo, 6-8 june 1988.- JIRA, Tokyo, 1988

[6] SHIOKAWA (T.), et al..- "Navigation/Positioning control of mobile robots for construction", in Fith International Symposium on Robotics in Construction, JIRA, Tokyo, 6-8 june 1988.- JIRA, Tokyo, 1988

[7] OSHI (T.),MIO (K.).-"A positioning system for mobile robots in construction applications-laser positioner", in : Fith International Symposium on Robotics in Construction, JIRA, Tokyo, 6-8 june 1988.- JIRA, Tokyo, 1988

[8] NISHIDE (K.) et al..-"A position and heading measurement system for robots-laser navigator-", in : Fith International Symposium on Robotics in Construction, JIRA, Tokyo, 6-8 june 1988.- JIRA, Tokyo, 1988

[9] SALAGNAC (J-L.).- Robotisation des opérations de construction.- Paris, Cahiers du CSTB, juin 1988