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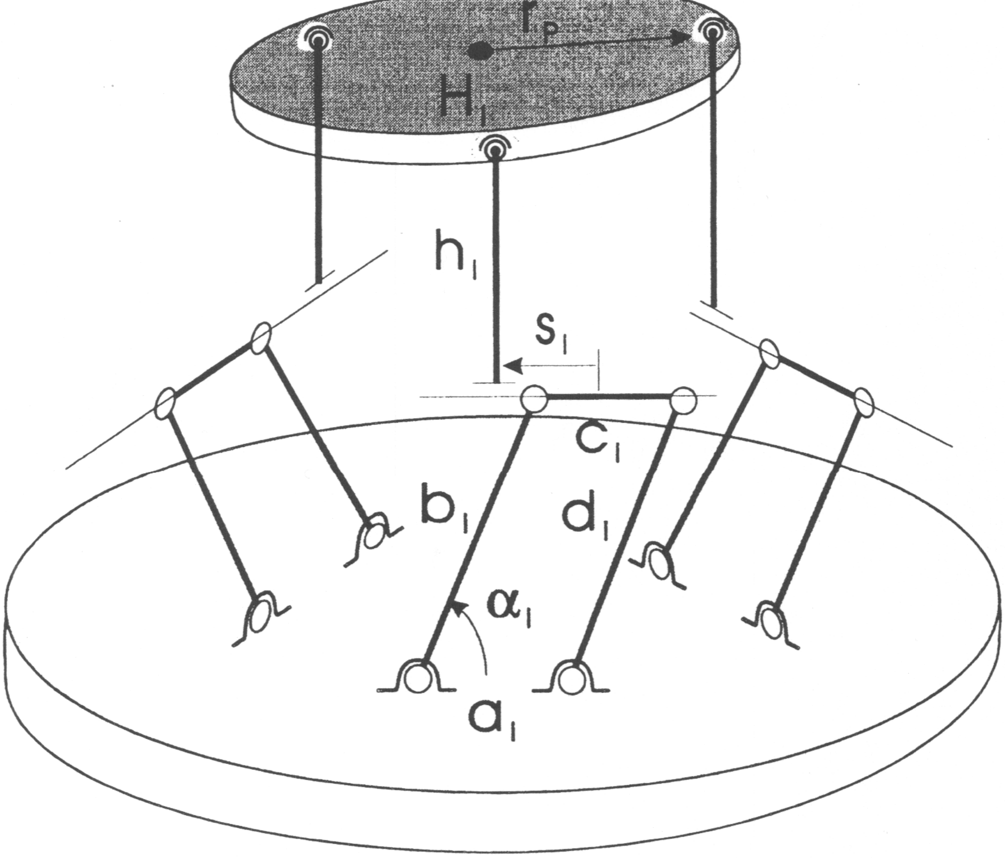

PROCEEDINGS

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LEONARDO - A MOBILE ROBOT FOR GALLERY VISIT USING INTERNET

Bojan Nemec, Bor Prihavec†, Franc Solina†
Jožef Stefan Institute, Ljubljana
Jamova 39, 1111 Ljubljana, Slovenija
†University of Ljubljana, Faculty of Computer and Information Science
Tržaška 25, 1001 Ljubljana
e-mail: bojan.nemec@ijs.si

ABSTRACT: The paper describes Leonardo robot for gallery visit. Leonardo is a mobile robot equipped with the video camera that is guided remotely using internet. It enables the internet visitor from any part of the world to visit the art gallery. The whole setup consists of a control computer connected to the internet, which recognizes internet commands and the mobile robot itself. Video camera is placed on 2 DOF mechanism at the top of the mobile platform. The commands are transmitted from the internet computer to the Leonardo mobile robot using radio remote control. The video image is broadcasted to the internet computer. The internet server computer digitizes the image and sends it on the internet.

KEYWORDS: Mobile Robots, Path Sensing, Remote Control

INTRODUCTION

In the past years the robotics research activities have spread to many nonindustrial areas of applications. It is a notable trend that the interests on R&D fields are changing from the manufacturing area to the human life area. Robots are going out from the factories into the human living environment. Service robots have become a reality and are used for many applications such as hospital porter, commercial cleaning, guard service, nuclear power maintenance, handicapped care, etc. On the other hand, we witness the information revolution introduced by Internet. The idea is to join these two technologies - service robots and internet. .

The idea of controlling robots via internet is not new. Researchers investigated the possibility of using internet for medical applications. First attempts were limited to sending live video image from surgery room from one place of the world to another, where an expert surgeon could on line advice his colleague who is actually performing the intervention. By using remotely controlled robot the intervention could be executed even without presence of the doctor in an emergency case [1, 2]. The similar applications are almost unlimited, including all kinds of equipment servicing (i.e. nuclear plants) [3, 4].

At the Jozef Stefan Institute and University of Ljubljana, we developed gallery visit robot Leonardo, that joins today's two most important information technologies - service robots and internet. Leonardo is a mobile robot that enables the internet visitor from any part of the world to visit the art gallery where Leonardo is installed.

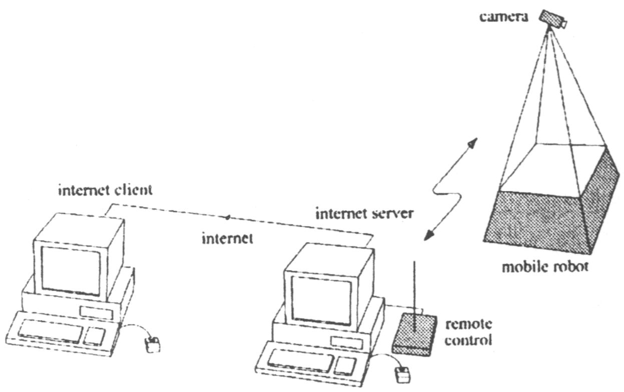

Figure 1: System overview

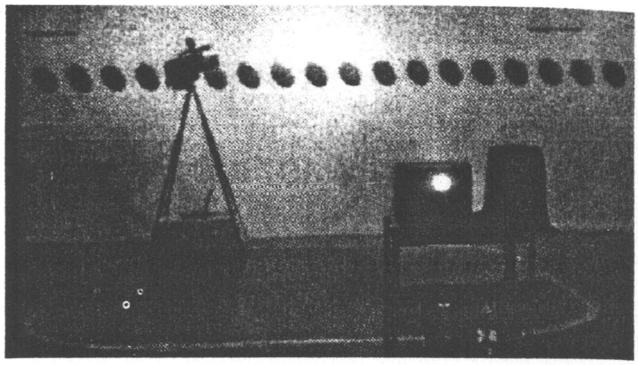

Figure 2: Leonardo in a gallery exhibition

SYSTEM OVERVIEW

The whole system setup is presented in fig. 1. The system consists of one mobile robot Leonardo, remotely controlled by internet server and one or more internet clients. However, only one internet client is active client, i.e. only one can control the movement of the mobile robot. Other clients are passive, i.e. they can receive video image by the mobile robot Leonardo, by they can not affect the Leonardo's controls such as camera movement and mobile platform movement.

While designing Leonardo, we had in mind the following goals :

- low cost
- safety
- autonomous guidance

Low cost was obtained by using technology for remote control of aircraft models, such as servo motors, radio remote control and TV image broadcasting. Leonardo moves in the gallery, where obstacles, i.e. gallery visitors can not be predicted in advance. Therefore, we had to implement the real time obstacle detection and avoidance by using ultrasonic range sensors and bumpers. Leonardo is an autonomous robot, but the moving trajectory is not completely free to choose. The moving path is prescribed by metal ribbon on the floor. Leonardo has a system for path tracking using inductive sensors.

MOBILE ROBOT

Mobile robot LEONARDO consists of two subsystems - moving platform and video camera subsystem. The schematic diagram of the mobile robot is presented in fig. 3 and its photography in fig. 2. Camera subsystem consists of two d.o.f. mechanism, allowing to move pitch and yaw orientation angles of the camera, system for broadcasting video image and CCD video camera itself. The yaw and pitch angles of the camera are remotely controlled by PCM radio link by feeding data directly from the PCM receiver to the servo controlled axes.

Moving platform has two servo controlled motors - one for steering mechanism and the other for driving wheel pair. These motors are controlled by PC compatible single board computer (SBC). SBC reads commands from PCM receiver and analog values, decodes them, tracks the selected path and constantly scans the obstacle avoidance sensors. Reference values from PCM receiver to motor servo board are transmitted as series of pulses with fixed frequency, but variable width. To reduce the computational burden of the SBC, we implemented hardware modulator of pulses width upon the control value from SBC, as illustrated in fig 4. This assures also the correct timing and pulse frequency of

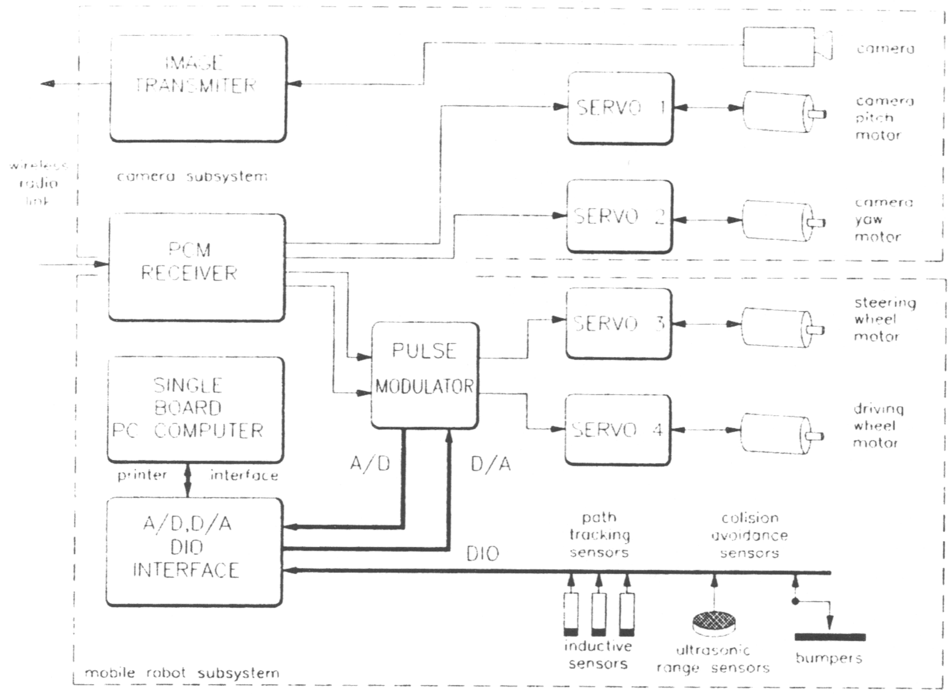

Figure 3: Scheme of mobile robot system

the PCM control signal.

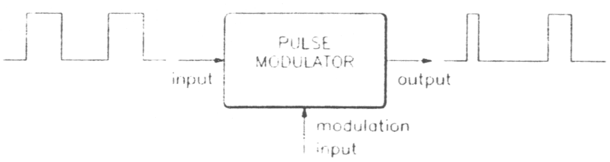

Figure 4: Command pulse modulation

Leonardo is powered by two 4.8 V NiCd battery packs, which enable average autonomy of about 2 hours.

PATH TRACKING

Navigation of AGVs has been intensively investigated in the past decade [6, 7, 5]. However, in order to reduce cost we had to choose simple and cost effective navigation method. Leonardo's path in the art gallery is defined by using ultra thin self adhesive metal ribbons on floor. Path tracking sensor is composed of three high sensitive inductive sensors. The path control algorithm is accomplished by using fuzzy logic rules. Namely, digital signals from force sensors can be naturally represented and fuzzy logic membership function. The fuzzy logic controller has two inputs - signals from the inductive sensors, previous (delayed) signals from the inductive sensors and two outputs - stearing angle and drive acceleration. The different membership function related to the inductive sensor signals are presented in fig. 5.

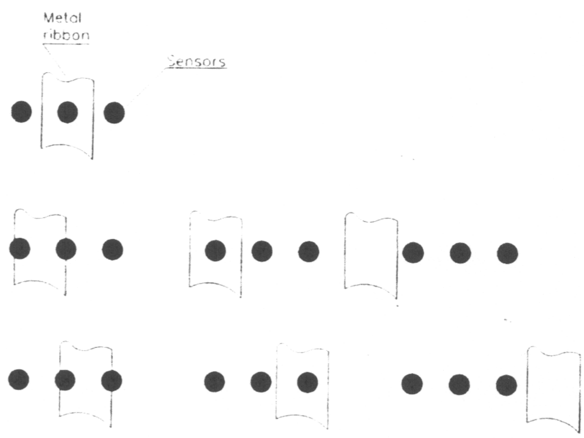

Figure 5: Possible sensor/metal ribbon poses

If the robot looses the path, it stops immediately and starts path searching procedure in the direction where the path was sensed in the past instants. Metal ribbon is used also to encode crossway in the art gallery and robot station in front of an art piece. At the crossway robot selects the direction upon the interactive command from the user or from the predefined navigation plan. Coding of crossways and stations are illustrated in fig. 6.

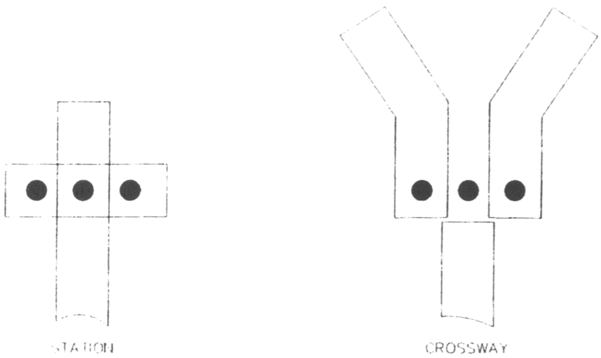

Figure 6: Station and crossway coding

During the navigation, Leonardo constantly scans obstacle avoidance sensors such as bumpers and ultrasonic range sensors. If an obstacle is detected, the robot stops for specified time interval and attempts to continue. In reality, Leonardo never avoids an obstacle by changing it's path, it simply waits until the obstacle (a visitor in the art gallery) removes from its path.

INTERNET SERVER COMPUTER

The internet server computer receives commands from the internet client and distributes them to the mobile platform using PCM radio transmitter. The block diagram of the internet server station is figured in fig 7. Actually, the radio transmitter is the same as used to control aircraft models. It can transmit up to 7 analog values and 5 digital signals. Analog signals are used to transmit the desired camera movement and desired robot direction (forward, backward, left, right, stop), while the digital signal is used to distinguish between autonomous guidance or remote control. Unfortunately, the only information which is send back from the robot to the server station is the video image from the camera. Thus, robot is controlled in open loop with a possibility of video inspection. The video image is processed by the image capture board and transferred via the internet to the client computer, where it is displayed. The maximum image transfer rate depends on type and compression ratio (quality of the image), image size and throughput capability of the net. Average transfer rate of an 320 x 240 pixels image is about 3 images per second.

GUIDING LEONARDO VIA INTERNET

Internet client interface is very simple. After accessing the home page of the gallery, the user can observe live video image from the gallery and short description of the art piece. If the visitor is the active client, it can control the robot using simple buttons as presented in fig. 8.

The following actions are available to the internet client:

- stop at the art piece. The internet visitor can rotate the camera, take a snapshot or continue to the next exhibit.
- stop at the crossing. The internet visitor can choose the desired path.
- go directly to the selected piece of art.

CONCLUSIONS

In the paper we have presented a mobile robot, which enables the internet client from one part of the world to visit the art gallery at another part of the world. While designing Leonardo, low cost was primary goal. Prices required for industrial setup of the similar capabilities are up to 50 times higher, which is unacceptable for the nonprofit application. In order to reduce cost, we had to scarify the performance of the system. Currently the main drawback is that the robot can not report its

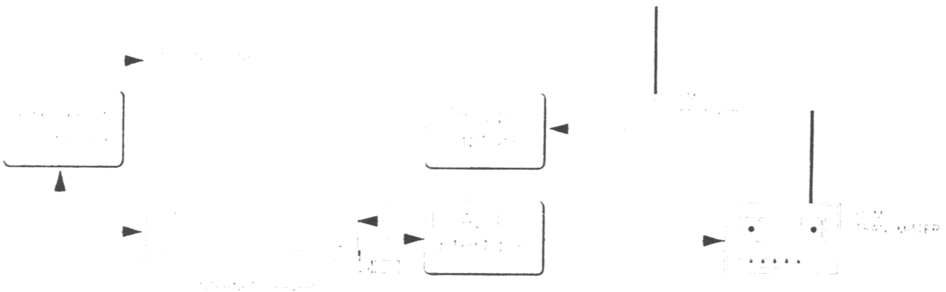

Figure 7: Internet server computer setup

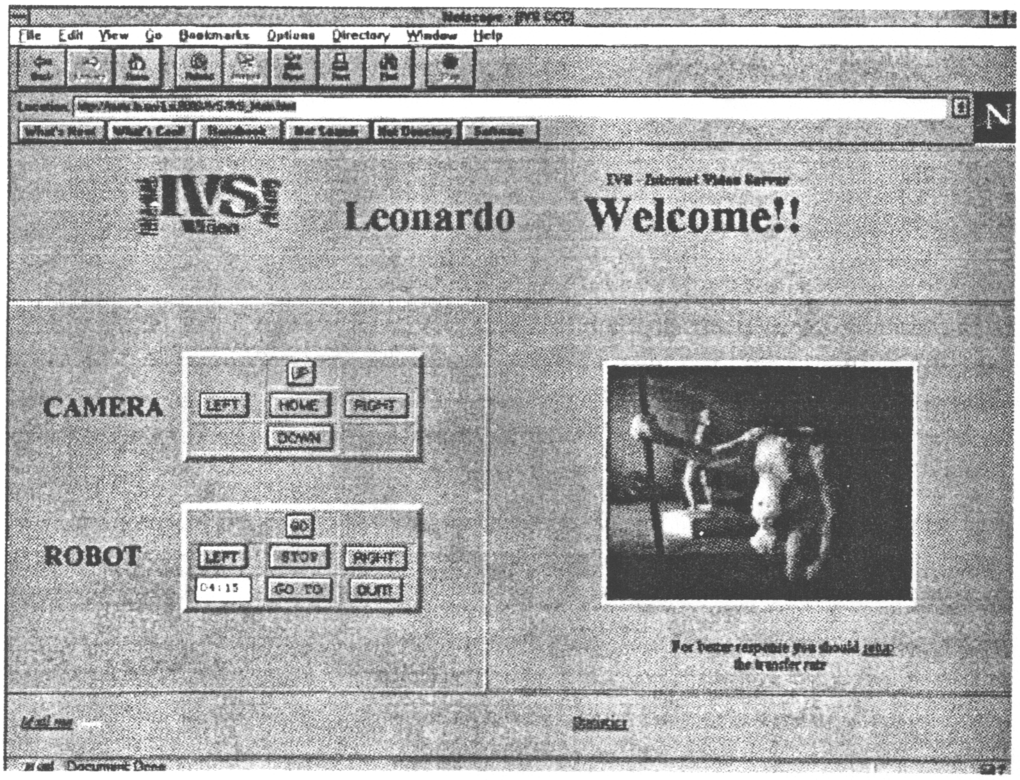

Figure 8: Client user interface

status to the internet station and therefore the control is mainly open-loop. In the future we will upgrade the system with additional sensors which will enable Leonardo to identify its position. Leonardo is an experimental setup and is not yet in regular use. However, we are convinced that it is the first member of newcoming family of service robots.

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