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Intelligent OkiKoSenPBX1 Security Patrol Robot via Network and Map-Based Route Planning

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Abstract: With an increased demand for security and limited numbers of trained security personnel, some security mangers have a lot of ground to police and limited staff to cover it. To compensate for shortages of security staffs and to reduce the stress of security managers, we have developed an intelligent patrol robot system called OkiKoSenPBX1. The system integrates a variety of sensors to gather environmental information and to detect abnormal events including intruders. To tackle this problem, the route planning procedure is used. This route planning is based on determining a sequence of intermediary goal points or coordinates x and y composing the robot trajectory. A qualitative running experimental evaluation has been performed as a preliminary practical implementation, where a student playing the role of a guard man takes control of the camera pan and tilt functions remotely. The performance of the developed system was excellence hoping to leave security personnel hands-free for other important tasks. The developed system can also be put into practical use in public offices, manufacturing facilities or various construction sites-everywhere there's a need for advanced frontline security.

Keywords: Intelligent patrol robot, security robot, wireless network

1. INTRODUCTION

A robot is a machine designed to execute one or more tasks repeatedly, with speed and precision. There are different types of robots as there are tasks for them to perform. Security robots are protecting property and documenting facilities autonomously around the world. An important aspect of robotic security systems is surveillance of specified area. They provide surveillance on wheels and may be one of the security industry's best kept secret. The Naval Postgraduate School in Monterey, California first attempted the concept of a fully autonomous indoor security robot in the late 1970s. Other agencies including NASA and US Government of Defense were also working on implementation of robotics technology. One of the first robots was ROBARTI, which helped face a full gamut of technical challenges. Subsequent robots grew in capability and with the end of the cold war; the technology was made available for sale to private firms through Reagan-Bush government to industry privatization. After a decade continuous development, security robot keeps as an intensive research issue because of its ever-increasing application to different places and its economical and technological relevance. Interesting application can be seen in robot scanning areas to find explosive devices [1]. With an increased demand for security and limited numbers of trained security personnel, some security mangers are turning to robots to help get the job done. To assist security manager we have developed a security patrol robot. The system consists of an autonomous mobile robot that can move independently outside as well inside the facility to be patrolled via deployed wireless internet device to that area. Due to the robot contribution and costs saving, many researchers have done a lot of significant work on security robot whose some of them can be found in [2, 3]. These works mainly focus on target perception and identification, robot localization, terrain map updating. But here we are interested specifically in investigating a very critical and still open issue that is paramount for the success of these applications: The route planning. The main goal is to generate a very convenient trajectory that can follow by the robot so that it increases as much as possible the probability of finding the intruders or abnormal events inside the surveillance region.

2. ROBOT PLATFORM

The OkiKoSenPBX1 shown in Fig.1 originally developed for Humanoid (HR) Robot. Using this approach, high-level control of the robot is maintained by a remote and local PC/server communicating by a secure wireless link. Low-level functionality is managed by an onboard digital signal processor while computationally intensive operations are performed off board. The result is a robot that's lighter, draws less power, runs longer and is dramatically less expensive than a fully bundled or self-contained system. Moreover, since primary processing resides in a server, any hardware upgrades to the central unit are shared by all the robots it controls. With its integrated high bandwidth (54Mps) wireless fidelity (Wi-Fi 802.11G) module, the system can upload all sensors data to a PC or server at rate , in excess of 10Hz. Similarly, streaming audio and video (up to 30 fps) either for direct monitoring or for processing by high-level Artificial Intelligent schemes is a snap. Commands and instructions sent to the robot via the same wireless link also pass at rates exceeding 10Hz, providing real-time control and access.

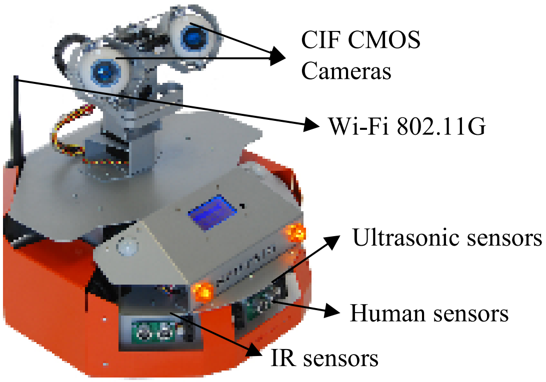

Fig.1: Robot with its equipped sensors

The OKiKoSenPBX1 includes all Wi-Robot development software components, enabling easy access to all data and information in a standard Microsoft Windows programming environment. Under the approach of using a separate PC for high-level control, there are no longer mobile system's processing power, memory and storage. For users of non-Windows operating systems OkiKoSenPBX1 can provide the raw communication protocol for direct integration with any other system or device.

3. ROBOT KINEMATICS

Robot considered in this study shown in Fig.2 is a differential motion with two degrees of freedom, composed by two active parallel and independent wheels, a third passive wheel with exclusively equilibrium function and proximity sensors capable of obstacles detection. The active wheels are independently controlled on velocity and sense of turning. Additionally the robot is equipped with specific sensors for detection and recognition of search objects or intruders. The robot model presents an interesting compromise between control simplicity and degrees of freedom that allow it to accomplish mobility requirements. Its motion is obtained by driving the active wheels. The resultant motion is described in terms of linear velocity v(t) and direction θ(t), representing on instantaneous linear motion of the medium point of the axis and a rotational motion or rotational velocity θ(t) of the robot over the same point.

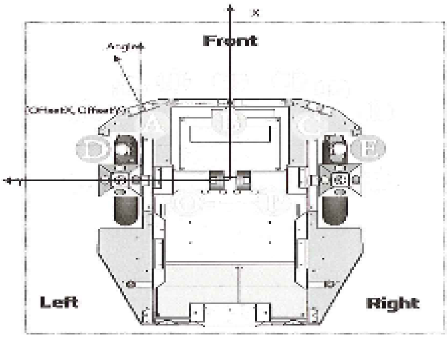

Fig.2: OkiKoSenPBX1 Robot sky view

The robot motion control is done by providing the wheels velocity $\omega_{left}(t)$ and$\omega_{right}(t)$, or equivalently the body linear and angular velocities v(t) and θ(t) called input or control variables. The mathematical model of the robot kinematics considers these two-input variables and three state variables: the robot position and orientation x(t), y(t) and θ(t), describe in the following equation:

$$\begin{bmatrix}\dot{x}\\ \dot{y}\\ \dot{\theta}\end{bmatrix} = \begin{bmatrix}\cos\theta & 0\\ \sin\theta & 0\\ 0 & 1\end{bmatrix} = \begin{bmatrix}v\\ \omega\end{bmatrix} \qquad (1)$$

These equations constitute a non-holonomic dynamical system. The control of this system has been studied extensively by various research groups, and diverse solutions are available, for example in [4,5] .The motion control strategy adopted in this work involved a state feedback controller proposed in [6], which is an appropriate approach to produce a desired trajectory described by a sequence of coordinates $x_1(t)$, $y_1(t)$. This means that the route-planning task is given by a specialized robot module, independent of the motion control module that sets intermediate position lying on the requested path. The adopted control law considers the geometric situation, where the robot is placed at an arbitrary configuration, that is, the position x , y and orientation θ, and a desired position is defined by the robot route planner. In the robot reference frame $X_R Y_R$, the configuration error vector is defined by $e = (\rho\varphi)^T$.

Where:

$$\left.\begin{matrix}\rho\\ \varphi\end{matrix}\right\} = \text{Target positions}$$

We defined the angle φ between the X_R axis of the body reference frame and the vector connecting the robot center and the desired position.

4. MAP-BASED ROUTE PLANNING

The planning procedure is based on determining a sequence of intermediary goal points or coordinates x and y that will compose the robot trajectory. The route-planning generator module uses an area-preserving map that is considered as a paradigm for area-preserving chaotic systems. This map, also called Taylor-Chirikov map [7]. It is a two-dimensional map which results from a periodic impulsive kicking of a rotor. This map was firstly proposed by Brian Taylor [8] and then independently obtained by Chirikov to describe the dynamic of magnetic field lines on the kicked rotor. The dynamic effect of this system is expressed mathematically through the map equations, given by:

$$\begin{aligned} \alpha_{n+1} &= \alpha_n + K \sin \beta_n \\ \beta_{n+1} &= \beta_n + \alpha_{n+1} \end{aligned} \qquad (2)$$

Where:
α = Periodic configuration variable or angular position
β = Momentum variable or angular speed

These map variables are both computed mod (2π). The map parameter K represents the strength of the nonlinear kick applied in the rotor mechanism. In its phase space and according to the value associated with the parameter K, it has stable and unstable periodic orbits, Kolmogorov-Arnold-Moser (KAM) surfaces, and chaotic regions. Depending on the nonlinear parameter K, the regions of regular motion and the regions of chaotic motion are complexly interwoven, but the chaotic regions are confined between KAM. As this parameter is increased, the KAM surfaces start to be destroyed, chaotic regions occupy increasingly large areas until, for a specific value of K, the last KAM is destroyed and the entire region of the phase space appears to be densely covered by a single chaotic orbit. Our route-planning generator module is implemented based on the map builder that presents this dynamics. Let us now show an example of how the map is used in the context of our route-planning generator module. By numerically simulating the map equations, we analyzed the properties of terrain covering considering the basic mission requirements for fast terrain scanning. We defined a terrain with different dimension in a normalized measurement unit. The map simulation begins with an arbitrary initial position, and considers the gain value K = 18. As the map equations simulation continues over and over, we noted in fact that, the necessary condition for the complete region to be patrolled is K > 18. The terrain covering can be judged through a performance index. This index is defined using a terrain division on square unit cells, and computing the visited cells percentage after the robot location planning.

5. CONTROL ARCHITECTURE

In our study wee associate a route-planning generator module with a closed-loop locomotion control module. At each step, the first one generates a position goal defined by its coordinates in the phase space. This position goal is provided to the second module, which drives the robot from its actual position to the desired one. When the robot arrives at the desired position, the route (path)-planning generator module is used again to give another position goal, which is subsequently provided to the second module. This sequence of action is repeated over and over again. The route-planning generator module is implemented by exploiting the dynamics of an area-preserving map in a chaotic regime. Different to a dissipative chaotic map, in which the chaotic evolution takes place on attractors, the chaotic region of an area-preserving map for specific parameter values extends practically over all of its phase spaces. For these parameter values, the entire phase space is covered by a single chaotic orbit. It is therefore possible to make an association between the physical regions that we wish to patrol with the phase space defined for the area-preserving map.

6. RESULTS AND DISCUSSION

The robot has three operating modes: Manual, Auto and Idle mode.

- In Manual mode, the robot relies on instructions from a remote user to navigate or controlled by mouse by first clicking the show control button in the control panel button on the left side of the program window. This will prompt navigation control panel. Alternatively the joystick shown in Fig.3 can be used to control the robot directly.
- In Auto mode the robot will wander its environment, using its build-in collision avoidance system to aid it from hitting any objects.
- In Idle mode the robot remains powered-on in a standby setting while minimizing power consumption.

To test our security robot patrolling approach, we have simulated the robot kinematic motion by starting with low speed, then automatically and gradually the robot adjusted its speed to reach the desired speed for the patrol mission.

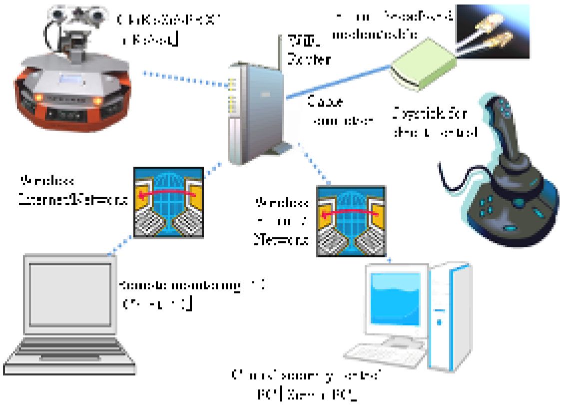

Fig. 3: Robot testing performance setup

Once the desired speed is reached it becomes constant throughout the patrol mission where it follows successfully the planned route and finished the first tour of the patrolling mission within the allocated patrol time set to 3 min (for the test purpose). The test has been repeated three times of which the robot did accomplish its mission successfully without colliding with any objects.
Next, to test the robot collision avoidance capability, two set of experiments have been done. The first test scenario consists of putting three chairs in the robot path then starts the robot from the remote monitoring computer. The robot has managed to get through the chairs and accomplished its patrol mission successfully again in the 3 min as expected. The second test consists of putting three chairs in the robot path as in the first test scenario and one big piece of wood just where the robot is expected to get out once avoiding these three chairs. The robot managed and gets through the three chairs, and once arrived in front of the wood it made a backward and changed direction without leaving its planned mission route, and then accomplished successfully its sixth mission with two seconds late. It was expected to finish it patrol mission in 3 min but instead of 3 min the robot arrived at the destination in 3 min and two seconds which is due probably to the backward. During the patrol mission through its two CCD cameras the robot sent a real-time video to the central security control computer, where a student like-guard took control of the camera pan and tilt-zoom functions remotely.

7. CONCLUSION AND FUTURE WORK

In this study, a map-based route planning for security patrol robot is presented. The approach of the proposed system consists of numerically simulate the map equations, and then analyzed the properties of the terrain covering considering the basic mission requirements for fast terrain patrolling. The system was verified in a real world experiment inside our College Campus Building. The performance validation test proves that the suggested system is able to accomplish its patrol mission successfully within the time required. The robot capability of avoiding any objects or obstacles has been also proven as the robot is able of making self-decision once faces an obstacle in front of it.

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