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Mobile Robot Surveillance Using the Phase of Passive UHF NFC Signals

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***Abstract*: This paper presents a global localization system for an indoor autonomous vehicle equipped with odometry sensors and a Near Field Communication (NFC) reader to interrogate tags located on the ceiling of the environment. The Near Field Communication (NFC) reader can measure the phase of the signals coming from responding tags. This phase has non-univocal dependence on the distance robot tag, but in the considered frequency, it is really sensitive to a change in the position of the robot. In this system is used for surveillance in security applications. For this reason, a multi hypothesis Kalman filtering approach provides a really satisfactory performance even in the case that a very small amount experimental tests, an average position estimation error of about 4 cm is achieved using only two tags for an area of about 5m^2.**

Keywords: NFC, Mobile Robot Surveillance.

I. INTRODUCTION

INDOOR localization of autonomous vehicles (or mobile robots) is a challenging and lively subject because of the complexity of the indoor scenarios, the diversity of technologies involved, and the commercial and industrial interests. Typically, the problem is solved by fusing the proprioceptive sensors information (e.g., odometry) with exteroceptive measurements, which, in absence of Global Positioning System signals, are obtained by laser, sonar, infrared, or visual sensors. In the last few years, a new kind of exteroceptive sensor based on radio-frequency identification (RFID) technology obtained a growing interest because of its cheapness and its reliability in many harsh environments (e.g., dusty, smoky, and dark), where other technologies may fail (a recent survey on possible approaches can be found. An RFID system consists of a set of transponders (tags), storing an identification code, and of a detector (reader), which is able to retrieve the identity of the tags through a wireless link. If the reader is installed on the robot, the tags can be placed in known positions of the environment as artificial landmarks. Since the identity of the tags is known to the reader, the data association problem is completely bypassed. RFID tags can be active (if they have an internal source of energy) or passive (if the energy is supplied by the electromagnetic coupling with the reader). This paper is focused on passive tags, which have the nice feature that a negligible level of maintenance is needed.

II. EXISTING SYSTEM

The existing system presents a global localization system for an indoor autonomous vehicle equipped with odometry sensors and radio-frequency identification (RFID) reader to interrogate tags located on the ceiling of the environment. The RFID reader can measure the phase of the signals coming from responding tags. This phase has non-univocal dependence on the distance robot tag, but in the considered frequency, it is really sensitive to a change in the position of the robot. For this reason, a multi hypothesis Kalman filtering approach provides a really satisfactory performance even in the case that a very small density of tags is used.

III. PROPOSED SYSTEM

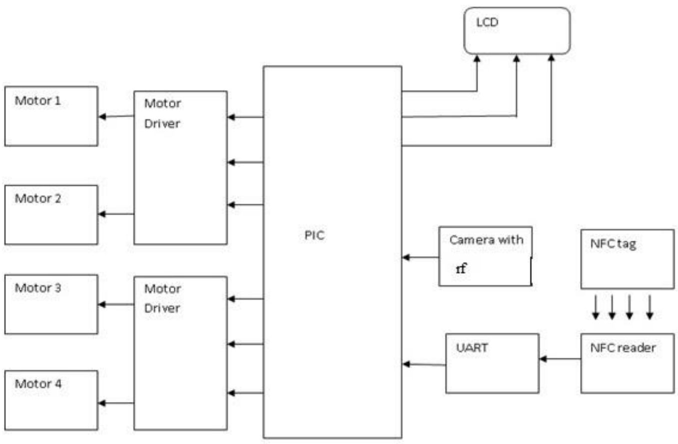
In this paper, a significant improvement on the system proposed in [9] is obtained by exploiting the phase of the tag signals. The advantage of the new method with respect to [9] is the reduction in the localization error of about an order of magnitude and of the transitory time (i.e., the time required by the estimation error to set to a steady-state value). In addition, the new method provides satisfactory localization results even in cases where the density of tags is so reduced and the path is so short that the approach proposed in [9] may fail. It must be remarked that, differently from most of the RFID-based methods proposed in the literature, which resort to a large number of tags to achieve localization, the method proposed in this paper is able to achieve global localization (i.e., initial robot pose unknown) even in the case of only two tags. This will be shown in this paper. To the best of the authors' knowledge, this is the first paper that proposes the use of the phase of passive UHF NFC signals for the localization of an indoor mobile vehicle.

In addition, differently from the aforementioned phase-based methods, our positioning algorithm directly exploits the phase coming from the tag's signals without additional calculations to determine range, bearing, or velocity. As the phase angle is very sensitive to the variation of the distance between a tag and the moving vehicle, i.e., about 1 degree/mm, the theoretical localization accuracy is in the order of a millimeter, whereas the accuracy achieved in the experimental activity is in the order of a centimeter. Furthermore, making use of high-directive tags (similarly to [9]), the phase measurement is less sensitive to multipath (with respect to Omni directional tags). Phase measurements, however, suffer from cycle ambiguity because of the 2π periodicity of the phase angle (the periodicity is π for technological reasons explained in this paper). Since this ambiguity does not permit to univocally retrieve the distance between the tag and the reader mounted on the vehicle, a suitable algorithm has been developed. The proposed approach is similar to the multi hypothesis EKF (MHEKF) used in to solve a localization problem characterized by an uncertain data association or to the particle Kalman filter (PKF) presented in a weather forecast context. Some major differences, however, characterize our method with respect to these approaches.

The MHEKF in and the PKF are both composed of a certain number of EKF instances, which autonomously evolve. In these instances are evaluated during the algorithm and can be deleted, generated, or split according to their likelihood, to new observations, and to the necessity of solving the ambiguity of data associations of new arriving measurements, respectively. In the EKF instances can be handled through a resembling procedure. In our case, the situation is different: We still have a number of autonomously evolving EKF instances, but the multi hypothesis is only concerned with the initial pose of the robot (we are dealing with a global localization problem). Since, as explained in this paper, a phase measurement is locally equivalent to a distance measurement and due to the fact that, according, an EKF provides excellent results when the distance from a set of landmarks is used, the idea is to initialize a bunch of EKF instances with the guarantee that at least one instance is close to the actual initial pose of the robot (this is possible due to the bounded ness of the detection regions associated with the tags).

Then, the problem will be to discover among the EKF instances the correct one: This can be very easily performed in a few steps by measuring, at each step, the likelihood of each EKF instance and by deleting those instances whose likelihood falls below a given threshold. Thus, our EKF instances do not split or add but can be only deleted during the evolution of the filter, with the result that their number rapidly decreases and, in a few steps, only one EKF instance survives. This is similar to the multi model EKF approach described. If, due to some un modeled noise or to an unpredictable event, the likelihood of all the EKF instances falls below another threshold, the algorithm is reinitialized: This makes the approach suitable also to solve a kidnapping problem.

BLOCK DIAGRAM



HARDWARE REQUIREMENT

- NFC Reader with tag
- PIC
- LCD
- Ultrasonic Sensor
- Motor
- Motor driver
- UART
- Camera with rf

SOFTWARE REQUIREMENT

- MPLAP software
- Embedded C

ADVANTAGE

- High speed
- User friendly
- Low cost

APPLICATION

- Industrial surveillance application
- Home surveillance application
- Mountain transport applications
- Indoor industrial transport applications

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