

Self-localization Capable Mobile Sensor Nodes

Extended Abstract

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I. INTRODUCTION

For the scenario of autonomous indoor navigating four-rotor flying robots, precise position information are required. Those quadcopters, as they are called, are already equipped with several on-board sensors, however, the exact position can neither be computed nor maintained due to measurement and other errors. Therefore, a dedicated localization system is needed, which, for autonomous space exploration, must be able to deploy itself in the environment. Several academic or commercial localization solutions already exist, e.g. the Cricket system [1], but no system can create a localization grid fully self-governed. For most systems, the reference points must be deployed manually as well as the information of the corresponding locations must be provided to the individual node. Few systems are designed to be self-localization capable but immobile, e.g. the DOLPHIN system [2]. If those systems are not placed properly, the self-localization algorithm might fail and, therefore, the whole grid might fail too. We advance the state of the art by providing a platform, which is capable of not only localizing the targets (flying robots) but also its own positions in relation to their neighbors. Thus, it is able to span up a grid in a self-organizing way. Additionally, to enable fully autonomous exploration for unknown environments, we also made those reference points mobile. Thus, it is possible not only to deploy the nodes automatically and to locally resolve line of sight problems, but also to react on changes in the environment.

II. LOCALIZATION USING MOBILE ANCHOR NODES

In this paper we present a multi-layer extendable robotic platform as depicted in Figure 1. The center of the unit is a SunSpot sensor node from Sun Microsystems. Besides the wired communication (we use the serial and the two wire interfaces), it is equipped with an IEEE 802.15.4 interface for wireless interaction. For mobilizing the anchor nodes, we developed a chassis

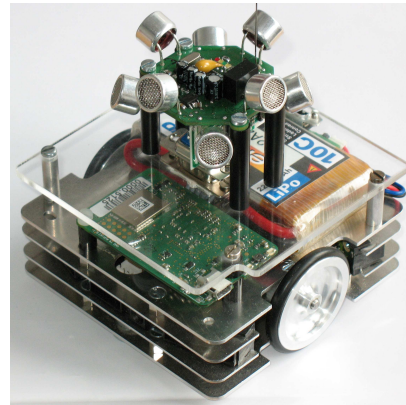


Fig. 1. Mobile anchor node

(10 cm \times 10 cm) consisting of two motors and six infrared distance sensors. In addition to two PID motor controllers for the velocity control of each wheel and an odometry for movement tracing, we integrated a position controller. This controller allows the robot to drive on splines using only a few supporting points. As those controllers are implemented on the driving layer, the actual sensor node has no excessive computational costs for the movement. For the near-field movement, the system is supported by infrared distance sensors to avoid collisions. For the far-field obstacle or neighbor detection, we also developed an ultrasound sensor system. The decision whether the measurement represents an obstacle or a neighbor node is made by performing an active (distance to obstacle measurement) or passive (listen to other active neighbor measurements) chirp. The detection array consists of four ultrasound units, each consisting of one receiver and one transmitter. Thereby, signals from the whole hemisphere can be detected. Additionally, not only distances but also the direction from the source of the sound can be calculated. For the flying nodes we mounted the sensor node and the ultrasound measurement unit on top of our quadcopters.

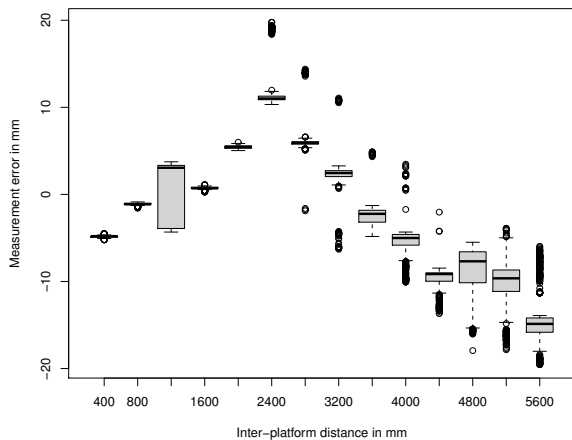


Fig. 2. Ultrasound accuracy

The ultrasound distance accuracy is plotted in Figure 2. For the measurement, two anchor nodes are placed on the floor. The error between the physical and the measured distance is depicted in the box-plot. An absolute accuracy of ± 20 mm can be achieved. In the worst case, the relative deviation is below 0.9%. The radius of coverage is up to 9 m, depending on the gain, the measurement type, and the ambient disturbances. By collection a sufficient number of distance information of the same chirp, detected by different nodes, a 3-dimensional position can be computed. Test results showed that the position controller relying on odometry measures should only be used for near-field movement, i.e. between two ultrasound localizations. The ultrasound position is exact (due to its global computation) but not always available. Because the odometry-calculated position is not accurate but always available, a fusion of both the ultrasound and the odometry systems should be used. The odometry position should be continuously updated by the ultrasound based localization results. For the collision avoidance in the near-field region, the onboard infrared distance sensors can be used. The sensor range is from 4 cm to 30 cm. To improve the route scheduling, the ultrasound system (active chirp) can be used. It can detect passive objects within a distance of up to 4.5 m.

III. CONCLUSION

We provide a modular and extendable platform for mobile sensor nodes with a wide application range besides our indoor localization system. The driving layer provides the feasibility to drive on a complex course using a few reference points. Additionally, it can detect obstacles on its route. The ultrasound layer offers a hemisphere

detection domain for distances and angles. Not only passive objects, e.g. walls, or active targets, e.g. the quadcopters, can be detected, but also neighboring nodes. Using this system, a localization grid based on anchor nodes can be spanned in an unknown environment without any configuration or manual deployment efforts. Locations of unsuitable sensor node placements, where no 3D localization is possible, or changing environments can be detected and corrected by autonomous repositioning of the sensor nodes. Besides our efforts to enhance the accuracy of the ultrasound system and the position controller, we investigated the real-time behavior of the localization system: For the flying robot, such requirements need to be considered because stopping and waiting is not possible. Therefore, the procedure has to be split into two parts. First, the mobile sensor nodes span up a grid. Secondly, the flying robot can rely on this system to maintain a position or course.

REFERENCES

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