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An Accurate 3D Localization Technique using a Single Camera and Ultrasound

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ABSTRACT

We have so far investigated a 3D localization system by using our original ultrasound ranging method called the Phase Accordance Method. Its highly accurate and stable performance (standard deviation (SD): 0.032 mm in the 3 meter measurement) allowed us to implement the system compactly (receiver unit size: 80 mm x 80 mm) and prove the acceptable level of 3D localization accuracy (SD: 24.9 mm). However, due to its poor GDOP (Geometric Dilution of Precision) value, the system often generated a large positioning error when small ranging errors were included in its trilateration processes. One reason for these errors was related to the phase characteristics of individual ultrasound transducers because of their directivity. We thus devised a phase characteristic compensation method and improved the accuracy of the system. However, it didn’t reach the same accuracy level as recent high-end commercial systems using multiple cameras (less than 1 mm RMSE).

In this study, we propose a novel technique by integrating a single camera and ultrasound. We use the extended Phase Accordance Method for accurately measuring the distance to a moving target and the camera for identifying a 2D position of the target on the image plane. A prototype system is composed of a transmitter unit mounting one ultrasound transmitter and three infrared LEDs surrounding it, and a receiver unit with one inexpensive camera and one ultrasound receiver. We implement these units in a lightweight and compact way (receiver unit size: 55 mm x 44 mm) to make the system robust to non-line-of-sight problems that frequently happen in trilateration or multi-camera based systems. Experimental results show that RMSEs of the prototype system are 1.20 mm and 1.66 mm in static and mobile (target speed: 1.0 m/s) settings, respectively. These indicate the performance of the system is comparable with that of the high-end systems.

KEYWORDS: 3D localization technique; Integration of ultrasound measurement and camera; Accurate ultrasound distance measurement; Compact system