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ORIGINAL ARTICLE

GNSS integration with vision-based navigation for low GNSS visibility conditions

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Abstract In urban canyons, buildings and other structures often block the line of sight of visible Global Navigation Satellite System (GNSS) satellites, which makes it difficult to obtain four or more satellites to provide a three-dimensional navigation solution. Previous studies on this operational environment have been conducted based on the assumption that GNSS is not available. However, a limited number of satellites can be used with other sensor measurements, although the number is insufficient to derive a navigation solution. The limited number of GNSS measurements can be integrated with vision-based navigation to correct navigation errors. We propose an integrated navigation system that improves the performance of vision-based navigation by integrating the limited GNSS measurements. An integrated model was designed to apply the GNSS range and range rate to vision-based navigation. The possibility of improved navigation performance was evaluated during an observability analysis based on available satellites. According to the observability analysis, each additional satellite decreased the number of unobservable states by one, while vision-based navigation always has three unobservable states. A computer simulation was conducted to verify the improvement in the navigation performance by analyzing the estimated position, which depended on the number of available satellites; additionally, an experimental test was conducted. The results showed that limited GNSS measurements can improve the positioning performance. Thus, our proposed method is expected to improve the positioning performance in urban canyons.

Keywords GNSS · INS · Integrated navigation · Low GNSS visibility · Vision

Introduction

Global Navigation Satellite System (GNSS) is a positioning system that is widely used in cars, ships, and airplanes because it can provide a position solution regardless of the time and location. In urban canyons, buildings and other structures often block the line of sight (LOS) of visible satellites, which makes it difficult to provide a navigation solution. GNSS availability simulations (Yoo et al. 2009; Lee et al. 2008) indicate that four or more visible satellites may sometimes be unavailable in urban canyons. Further, the application of GNSS fault detection and exclusion may reduce the number of available satellites because erroneous satellites are excluded (Lee et al. 2011).

Research into alternative navigation systems has been conducted because of constraints on the availability of GNSS in urban canyons. Zhao (1997) and Fu et al. (2007) estimated the position and heading based on the number of revolutions of each wheel using an odometer. In odometer applications, navigation error arises from wheel slips and inaccuracies in the scale factor of the odometer, which results in a drift error due to the absence of error correction using external information. The Inertial Navigation System (INS) can also be used as an alternative navigation system independently of GNSS (Titterton and Weston 1997). INS

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