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Comparison of two 2D laser scanners for sensing object distances, shapes, and surface patterns

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ABSTRACT

Laser scanners are increasingly used in automation and robotic applications as a sensing device for navigation and safety. They have agricultural applications in measuring plant growth rate, tree volume, tree count, 3D imaging, and pattern recognition. Laser scanners are commercially available, but there is very little published information on characteristics and performance of these laser scanners. This study compared two laser scanners, the Sick LMS200 and the Hokuyo URG-04LX, for measurement drift over time, the effect of material and color on measurement accuracy, and the ability to map different surface patterns.

Measurement drift over time was studied by determining the distance between the laser scanner sensor and a stationary object at different fixed distances and angles. Distance measurements over time fluctuated with a peak-to-peak value of 10–20 mm. The settling time, which is the time required for the averaged distance data to reach a stable level, increased when measurement distance increased but for a given distance, the settling time remained constant for different angles. At the measurement angle of 90°, the settling times for the LMS200 and the URG-04LX for 50% of the maximum scanner measurement distances were 53 min and 70 min, respectively. Therefore, to obtain accurate distance measurements, the laser scanners should be warmed up for the duration of the settling time before recording measurement data.

The measured distance for soft material objects, such as a styrofoam plate and a sheet of dry sponge, was longer than the actual distance. For shiny objects, such as orange tree leaves, transparency film, and a stainless steel plate, the measurement distance was shorter than actual distance. At the measurement angle of 90°, the difference between the longest and shortest measured distance (90% of the maximum scanner measurement distance) was 21.3 mm for the LMS200 and 29.7 mm for the URG-04LX. At the measurement angle of 45°, this difference increased to 73.2 mm for the LMS200; the URG-04LX was not able to detect any objects at 45°.

The surface shapes of a cylindrical pipe, a folded cardboard plate with a square-shaped valley, and a folded cardboard plate with a V-shaped valley were well-depicted by the laser scanner. For the object with a V-shaped valley with a true depth of 6.1 cm, the averaged depths measured by the LMS200 and URG-04LX were 6.8 cm and 3.6 cm, respectively. The larger discrepancy in the URG-04LX depth measurement may be caused by the relatively lower angular resolution of the URG scanner, compared to that of the LMS scanner.

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1. Introduction

For agricultural and industrial applications, the distance to a target object is a valuable measurement because it can be used for determining a variety of other measurements. For example, objects in an open space can be detected and counted by measuring the distances to the objects. Even the positions and shapes of the objects can be obtained. Distance measurement can be useful information in generating the surface topography of a target object, like for example, fruit trees. The 3D image of an object can be also reconstructed using distance measurements, obtained by moving a sensor in a 2D plane.

With advances in sensing technology, various types of sensors for distance measurement have been developed. Among them, sensors which use lasers have shown dominance. A laser is a light source device which converts external energy into electromagnetic radiation. The word LASER came from an acronym for light amplification by stimulated emission of radiation, but it is now accepted as a single word. What differentiates a laser from other light sources is that a laser beam has a single wavelength, a same phase, and high energy density. Thus, a laser beam can travel to quite a long distance in a straight line, maintaining a narrow beam. Because of this characteristic, lasers are commonly used as a sensing source for distance measurement.

A laser scanner, which is also called a laser radar or a laser range finder, is a non-contact optical device that measures the distance to an object in a scanning field using a pulsed laser beam. The scanner's measurement is based on the time-of-flight (TOF) principle. A laser source inside the scanner emits a pulsed laser beam. If this beam hits an object, part of the beam is reflected back to the scanner and hits a detector inside the scanner. The time between transmission and reception of the pulsed signal is directly proportional to the distance between the scanner and the object. The laser pulse is diverted sequentially with a specific angular interval using an internal rotating mirror. Thus, a fan-shaped two-dimensional scan is made of the surrounding area.

Laser scanners are becoming a common sensing device to aid the steering device to avoid obstacles, and in mapping environments for use in robotics and agricultural applications. Jiménez et al. (1999) built a laser scanner-based measurement system to recognize fruits in field tree conditions, considering it as a sensing device for a fruit-harvesting robot. The scanner provided the distance to an object and the attenuation of laser signal which occurred in the round-trip travel to the object. The information obtained was merged to recognize the fruit and find the final fruit position. Hebert (2000) compared the characteristics of several range sensing technologies used in robotics. The measurement range of a laser scanner using the TOF principle was relatively long, compared to other technologies. The scanner provided relatively stable, accurate measurements under hostile environmental conditions such as fog, dust, or smoke. Monta et al. (2004) built a three-dimensional sensing system, composed of a laser scanner and a scanner table moving vertically, for an agricultural robot. The sensing system could detect objects such as tree trunks, branches, and leaves in a vineyard, and calculate the diameter of the tree trunk and the distance between the tree trunks. Kise et al. (2005) presented an obstacle detection and identification algorithm of a laser scanner-based sensing system for autonomous agricultural vehicles. The sensing system was capable of detecting a moving object within a semicircle of an 8 m radius and reconstructing a 2D silhouette of the obstacle progressively in real time. Subramanian et al. (2006) developed machine vision and laser scanner-based guidance systems to navigate a tractor through the alleyway of a citrus grove and compared the performance of these systems. They reported that the laser scanner-based guidance was the better guidance system for straight and curved paths.

Measuring the surface topography of soil and plants or knowing the shape of an object is important for many precision agriculture applications. For this, laser scanners have shown great potential. Darboux and Huang (2003) developed a laser scanning system composed of two diode lasers and a digital camera to measure soil surface microtopography. Gonzalez et al. (2007) demonstrated the capability of a 3D laser scanning system, which consisted of a laser transmitter and two cameras, in describing the evolution of an underwater sediment bed in real time. Ehsani and Lang (2002) developed a laser scanner-based plant volume measurement system. The system was able to measure plant volume and height, indicating the possibility to measure the biomass and leaf area index of the plant. Wei and Salyani (2004, 2005) showed the potential of a laser scanner for simultaneous measurement of tree canopy height, width, volume, and foliage density. While applications of laser scanners in automation, robotics, and agriculture are increased significantly in the recent years, very little published information is available on characteristics and performance of these laser scanners.

2. Objectives

The overall goal of this study was to analyze and compare the characteristics of two commercially available laser scanners. The specific objectives were: (i) to test distance-measurement drifts over time at different measurement distances and angles, (ii) to examine the effect of different materials and colors of target objects on distance measurements, and (iii) to measure accuracy in mapping the surface patterns of the objects of different shapes.

3. Materials and methods

Two laser scanners, LMS200 (Sick Ag, Germany) and URG-04LX (Hokuyo Automatic Co., Japan), were used for the tests (Fig. 1a). Their specifications, provided from the manufacturers, are shown in Table 1. The LMS200 has a longer measurement distance, larger size, and is heavier compared to the URG-04LX. It also has the ability to change angular resolution. To control the scanners and download the measurements to a computer, a computer program was written using LabVIEW (National Instruments Co., Austin, TX).