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3DOD: A Haptic 3D Obstacle Detector for the Blind

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Abstract

In this article, we propose a haptic 3D obstacle detector for the blind, which combines an off-the-shelf 3D Time-of-Flight (ToF) camera and a novel 2D tactile display. The system detects objects in up to 7 meters, and renders the spatial layout of obstacles in a non-visual interface, allowing users to choose a route independently to avoid varied obstacles, including hanging obstacles.

1 Introduction

For the blind, the white cane is a very common and useful tool to explore the physical world safely and independently. But it is hard to perceive obstacles over waist and unexpected holes, specifically the dangerous obstacles at head level (Manduchi& Kurniawan, 2011). In this paper, we introduce a novel obstacle avoidance system for the blind to detect multiple obstacles at the same time and to present a precise spatial layout on a 2D multi-line Braille display, rather than presenting obstacles one by one. In addition to the 2D tactile display and a vibrating handheld controller as its haptic user interface, the proposed system employs an off-the-shelf 3D time-of-flight (ToF) camera to detect a larger area than by white canes, and an effective clustering algorithm to segment different obstacles. Furthermore, a set of abstract tactile symbols is used to represent the various obstacles according to types (e.g. floor-based obstacles, hanging obstacles) and sizes.

2 Related Work

Since about 1960s the ultrasonic sensor and infrared/laser sensors have been utilized to detect obstacles for the blind, and they are integrated into commercial assistive products, such as

UltraCane[1]. A couple of optical aids (e.g. digital cameras) have been demonstrated (Meijer, 1992) and have been improved considerably. However, through the 2D digital cameras it is time-consuming to calculate precise distance and orientation of obstacles, and it's hard to work in dark environments. Recently, the infrared-based depth sensors are employed to overcome the disadvantages of the 2D digital cameras, such as the structured light based Kinect (Zöllner et al, 2011). Compared to structured light based depth sensors, the 3D ToF cameras is considered as another kind of promising depth sensors (Sergi et al, 2011) to obtain precise distance pixel by pixel and perform well outdoor.

To present the obstacles in non-visual channels, the acoustic feedback and haptic feedback are the main methods. Even if the acoustic representation is a low-cost method and used widely (Meijer, 1992), it is difficult to inform the blind about the accurate distance and direction via frequency and amplitude of sounds. Besides, the audio output might interfere with hearing the surrounding environments. Haptic representations notify users through tiny vibrators against their skin or fingers. For instances, the NAVI project (Zöllner et al, 2011) used a waist belt with 3 vibrators. Due to their low resolution, those vibrotactile displays fail to present the spatial layout with multiple obstacles at the same time.

3 3D Obstacle Detector

3.1 System Overview

We developed a 3D obstacle detector (3DOD) to help the blind locate and avoid surrounding obstacles. The system combined an off-the-shelf 3D ToF camera and a novel tactile display at the first time, see Figure 1. The 3D ToF camera can detect up to 7meters with a large field of view (70˚ horizontally and 50˚ vertically), and obtain direct distance to objects pixel by pixel (160x120). The tactile display has an array of 30x32 pins and can be refreshed typically at 5Hz. In addition to its multiple on-board buttons for inputting, a Wii remote controller integrated into a common white cane can be used to notify users promptly if there are some closed obstacles by its built-in vibrator. Besides, the portable computer in a knapsack runs the 3DOD system.

3.2 System Procedure

In brief, there are two basic steps in the system. The first one is to detect the surrounding environment by the 3D ToF camera, and the next one is to represent the spatial cues in haptic user interfaces for the blind. For example (see Figure 2), after capturing the 3D scene a clustering algorithm will be used to segment obstacles one by one and calculate properties, e.g. distance, orientation, type, and size. If there are one or more obstacles closer than 2 meters distance, the vibrator on the WiiCane will work in a short amount of time to warn users. Then

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[1] http://www.ultracane.com/

the users can explore the tactile display to locate the obstacles and find out a clear path independently. Note that users don't need all the time to touch the display to find if there is one obstacle nearby, which will reduce users' cognitive loads by two hands while walking.

Figure 1: The 3DOD system overview. (a) A subject wears the 3DOD system; (b) A 3D TOF camera (weight 1kg); (c) A portable multiple line Braille display (weight 0.6kg); (d) A portable computer;

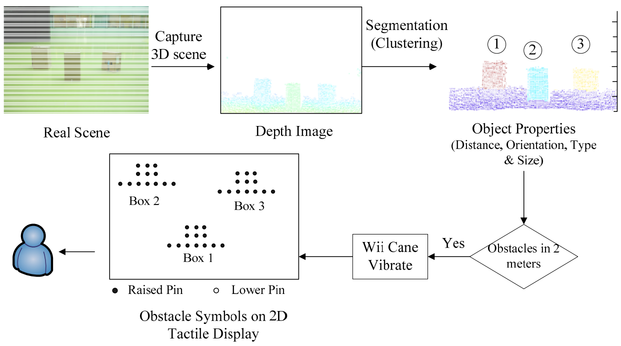

Figure 2: The system procedure to detect and represent obstacles

3.3 3D Segmentation

We improved the density-based spatial segmentation algorithm (Klasing et al, 2008) and handled with 3D point clouds data captured by the 3D camera nearly in real-time. By finding and merging nearest neighboring points, the algorithm can segment different objects through two pre-defined parameters, the clustering radius and the minimum number of points in one cluster. The algorithm was programmed in VC++, and typically would segment a 3D scene within 20-50 ms, depending on the complexity of the scene.

3.4 Haptic User Interface

In addition to the vibration-enabled WiiCane, we utilized a novel tactile display consisting of an array of 30 by 32 pins, to represent a precise spatial layout of obstacles and obstacles' properties via abstract tactile symbols. As shown in Figure 3, the display can render obstacles closed to 4 meters in front of users. Its horizontal reference grid indicates the bound up to 2 meters, while the vertical one matches with the users' heading orientation. The obstacle symbols were presented at corresponding positions on the display, according to their distances and orientations in the real world.

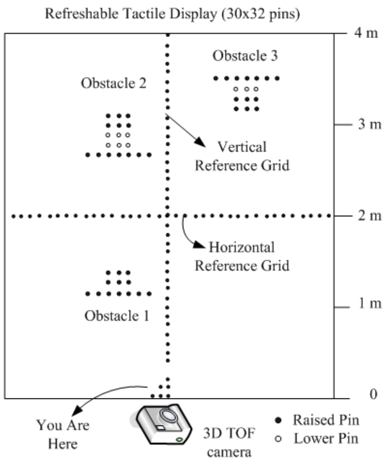

Figure 3: The spatial layout of obstacles on 2D tactile display

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