High resolution pressure sensing
using sub-pixel shifts on low resolution load-sensing tiles *

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I. INTRODUCTION

Ambient intelligence explores how sensing environments can interact with their inhabitants. We are interested in employing the sensors embedded in the environment for analyzing the activity of humans inhabiting it.

This work is a result of our exploration of load sensors' capabilities. The goal is to recognize the actors and the activities performed on sensing surfaces by analyzing the forces perceived by the surfaces. Our previous work has centered on detecting, tracking and recognizing static and dynamic entities in the environment using load-sensing floors [2]. This was done in the context of the *Personally Assisted Living* Inria project, that aims to develop ambient and artificial intelligence for human assistance.

This paper presents a technique for scanning the surface in contact with the load-sensing floor. It employs sub-pixel shifting to make a series of low-resolution scans, which are then assembled into a high-resolution scan. It exploits the information contained in the differences between the shifted scans, and aggregates this information to compute a composite pressure scan. This technique calculates the weight transfer between the tiles when the analysed object slides over them. By using only the recorded weight and changements in the position of the center of weight, the scanner is able to reconstruct the contact surface of the object that slid on it.

Similarities can be identified between the pressure-sensing and imaging domains. The pressure perceived by a load-sensing surface is analogous to the amount of light perceived by an image-recording sensor. Both in imaging and pressure sensing, the sensor can be shifted by less than a pixel width to register a slightly different part of the incoming light or pressure. Such imaging techniques that construct a high-resolution image from several low-resolution images containing sub-pixel shifts have been proposed by Peleg et al. [4], Keren et al. [3], Tekalp et al. [5] and Tom et al. [6].

II. METHODOLOGY

The instrument we use for scanning is constructed of 4 load-sensing tiles (see Fig. 1). The tiles have vertical and horizontal frontiers between them, that measure the flow of weight between the tiles (see Fig. 2). The object to be scanned is slid with alternative horizontal and vertical translation movements over the plates (see Fig. 4a), allowing the entire object surface to be scanned. After each translation movement, the tiles measure the weight of the object portion standing on them (see Fig. 2b). Thus, at each step, the 4 tiles generate a low-resolution 4-sliced image of the load on the contact surface. These images are then assembled into a single grid-like high-resolution image of the contact surface (see Fig. 3b). The displacement brought by each translation can be measured by tracking the center of pressure of the object on the scanning surface. The distance travelled by the object's center of pressure corresponds to the distance travelled by its bounding box.

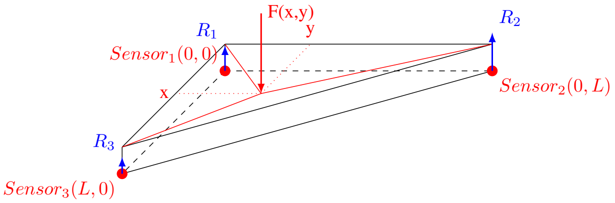
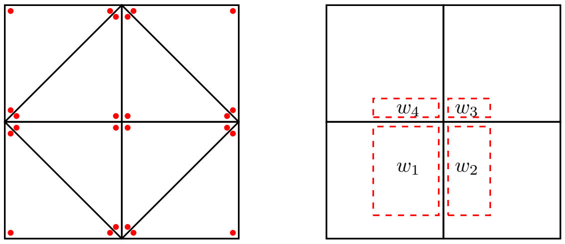


Fig. 1: Load distribution on an isostatic tile



(a) Scanner composed of 8 isostatic tiles. Load sensors represented as red dots.

(b) Each scan generates a 4-sliced image of the weight distribution inside the object's bounding box.

Fig. 2: The construction of a surface pressure scanner.

The problem can be schematically reduced to determining the weight of each pixel in the load-image representing the contact surface of the analysed object (see Fig. 3). Any given two load images can be assembled into a higher resolution image if both are subdivided by a common x or y line. This line is used for aligning the two images, creating the additional high-resolution image subdivisions. Fig. 4 offers an intuition on the way the algorithm executes itself.

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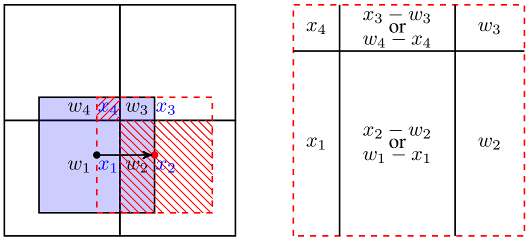
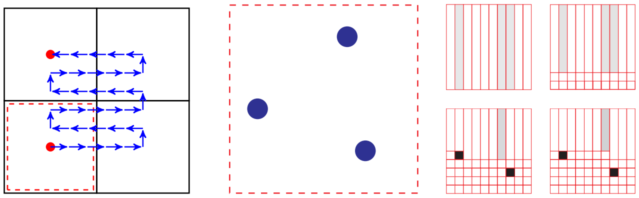


(a) Overlapping of two low-resolution load images.

(b) Aggregate of two overlapping low-resolution load images.

Fig. 3: Construction of a high-resolution image from low-resolution images.



(a) Object sliding over the scanning surface.

(b) The surface to be scanned.

(c) Scanning phases.

Fig. 4: Sample scan execution on a simulator. As the scanning progresses, the pressure image gets richer in detail. The ratio of weight to surface size is color coded in grayscale.

III. EXPERIMENTAL RESULTS

Experiments have been done both using a simulator of load-sensing tiles, and using a real-world implementation of the scanner. Fig. 5 shows simulation results for surface pressure scanning, that were obtained at different resolutions.

The physical experiment was implemented on a scanner composed of square sensing tiles, 60 cm x 60 cm in size, each equipped with 4 load sensors, as shown in Fig. 6b. The scanned object was a chair with a trapezoidal base, loaded with 40 kg of weight for a higher signal/noise ratio (see Fig. 6a). The chair position was measured by hand using millimeter paper. The results are presented in Fig. 6c.

IV. CONCLUSION AND PERSPECTIVES

This system can be used for measuring the weight distribution on surfaces: checking for abnormalities on weight distribution between the front and rear driving axles of vehicles on transportation lanes or railroad tracks. In an industrial setting, this technique could be used for measuring the density in each slice of a block of metal or other material. In the context of sensing environments equipped with floors consisting of this type of load-sensing tiles, this scanning system could provide a way for non-intrusive object recognition.

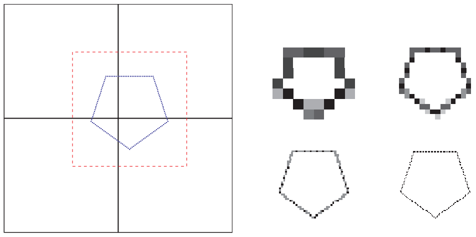
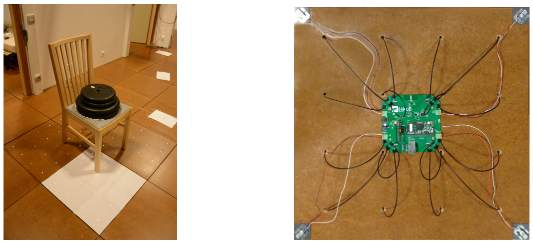
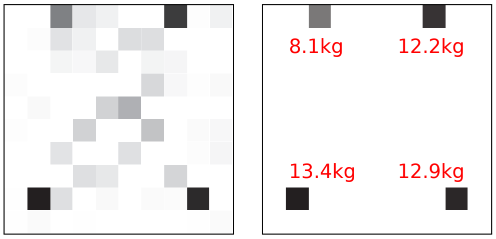


Fig. 5: Scanning at different resolutions.



(a) A chair being scanned on a scanner made of 4 load-sensing tiles. Millimeter paper is used as a location reference.

(b) The underneath of the load-sensing tiles used, showing the load sensors located in the corners.



(c) The pressure scans obtained before and after noise filtering. The perceived pressure is rendered as an equivalent weight value at 1G acceleration.

Fig. 6: Physical implementation of the pressure scanner.

Open problems include finding the optimal scanning trajectory, reducing measurement noise, and identifying objects without the need to scan them in a regular fashion, but rather while they are in motion. New features should be conceived for these pressure images, in order to use them for object recognition.

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