# Cavity Shape from Parallel Linear Shading: A Low-cost Technique to Collect Data for an Image Mining Oriented Geoprocessing System

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**Abstract.** An Image Mining oriented Geoprocessing depends essentially on spatially defined information from images. So it is possible to support decision-making quite suitably in several areas, such as environment management, urban management and health care. When large-scale use of image capturing and interpretation devices becomes possible, it seems attractive to have low cost additional infrastructures. This paper discusses the extraction of geometric features of cavities, primarily motivated by the need for monitoring patients with wounds called pressure ulcers (PU). An image with linear shadows on the cavity of a model is generated in order to enable the measurement of its deformation caused by depth. This yields maximum depth and volume in an experimental model that are compared with measurements made previously in a conventional manner. Differences with conventional measurements are partially satisfactory and suggest further improvements in image capturing device and computational procedures.

## 1 Introduction

An Image Mining oriented Geoprocessing depends essentially on spatially defined information from images. The use of information from images to support decision-making is quite suitable in several areas, including environment management, urban management and health care. Cost reducing in computing devices with higher

Ferreira da Rocha Júnior E., Gonçalves da Silva V., da Veiga Guadagnin R., Aniceto Santana L., de Souza Neves R. and Antonio Iturri de La Mata J. (2010).
Cavity Shape from Parallel Linear Shading: A Low-cost Technique to Collect Data for an Image Mining Oriented Geoprocessing System.
In *Proceedings of the Third International Workshop on Image Mining Theory and Applications*, pages 115-121
DOI: 10.5220/0002964001150121

performance are more and more motivating the implementation of computational procedures for information mining from images [1].

When large-scale use of image capturing and interpretation devices becomes possible, it seems attractive to have low cost infrastructures. Simple use, portability and robustness requirements are also relevant, since the devices are supposed to be manipulated by users with varying abilities, in different locations, with similar ilumination conditions.

This paper discusses estimation of geometric features of cavities, primarily motivated by the need for monitoring of patients with wounds called pressure ulcers (PU). An image with linear shadows on the cavity of a model is generated in order to enable the measurement of its deformation that is caused by depth. This yields maximum depth and volume in an experimental model that are compared with measurements made previously in a conventional manner.

## 2 Problem Statement

A pressure ulcer (PU) is defined as any change in skin integrity, which occurs mainly by shear force, friction or pressure that affect skin for an extended time. An external pressure of 50 to 200 mmHg leads to decreased capillary circulation and creates local ischemia, leading to tissue damage and tissue necrosis and so tissue death [2], [3], [4].

A PU has predisposing factors such as high age, comorbidities, and nutritional changes in the level of consciousness [3]. They cause increased morbidity and mortality in bedridden patients that have chronic diseases and elderly. They can make healing process more complex, increase the risk of infection and reduce its patient functional independence [2], [4].

To evaluate the geometrical properties of a PU one can use invasive techniques such as use of probes, rulers, filling with some saline or arginate solution, and non-invasive techniques that are more precise, such as laser scans through the technique from Vision Engineering Research Group (VERG) and Structured Light Method (SLIM) [5]. They are however quite expensive [6]. Image processing is very helpful for PU area estimation [7], [8], [9]. Initiatives on volume estimation are so far mainly based on punctual but not linear stripe images [10].

This paper presents a low-cost technique to calculate the volume of a PU with ambient light, through generation of linear shadows, image capture and computational analysis. Such low cost technique is an effective support for assistance of PU patients.

## 3 Material and Methods

The technique consists of illuminating the cavity, image capture and computer analysis of the image. A model of the back of an adult was built, using PVC heated by a steam engine. A PU simulation in the sacral region was done by means of a sphere with 8cm diameter. (See Fig. 1).

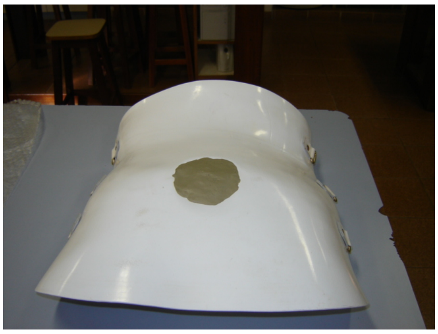

**Fig. 1.** Adult back model with filled cavity.

A 50cm long pipe, with a light bulb at one end and a 12cm x 20,5cm board with parallel grooves in the other end was constructed. (See Fig. 2 and 3) This device was set at an angle of 20 degrees with the vertical axis to the surface of the cavity. The cost of the device was ca. 130 reais ($72).

**Fig. 2.** Illumination device.

Back model was previously opaque gray painted to eliminate brightness. Image capture was made by digital camera in a vertical axis. The picture was taken during the day in an environment with subdued lighting. (Fig. 4). Linear stripes were so projected in the cavity model. The cost of such camera is about 500 reais. ($ 280).

A Java program was developed for image graying, thresholding, salt and pepper and sweeping filtering, and edge enhancement using gradient technique. So cubic polynomial Hermite curves were defined, based on pairs of points and their slopes in areas outside the cavity [11], [12], [13], [14], [15]. The spaces contained by these curves and the curves generated by the illumination lines are shown in Fig. 5.

**Fig. 3.** Board with slots.

**Fig. 4.** Cavity image.

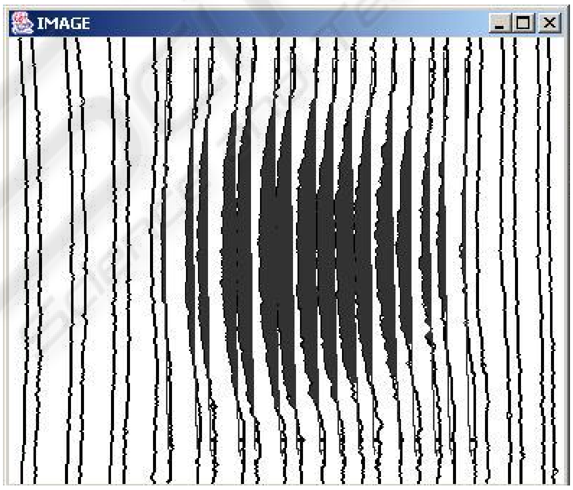


**Fig. 5.** Space difined by Hermite curves.

The greater distance between the curves in all of these areas was found.

The horizontal amount of pixels per cm is the ratio between the number of pixels corresponding to the distance covering all lines and the corresponding measure in cm multiplied by co-sinus of the illumination angle. This correction eliminates the deformation caused by illumination angle. The corresponding vertical amount of pixels is the same ratio but without co-sinus correction. The product of these values is the ratio of pixels per cm$^2$. The total area is the sum of the pixels of all spaces, divided by this ratio.

The maximum depth is obtained by division between the greater distance between the curves and the horizontal amount of pixels per cm.

The volume can be derived as follows, where the stripe width is 0,5 cm [10].

V (cm$^3$) = total area (cm$^2$) x stripe width (cm) / tan 20$^0$

## 4 Results

The measure of actual volume of simulated PU cavity was 43 cm$^3$. The maximum depth of 1.4cm was measured by a ruler from the bottom to a curved paper surface over the cavity. A 45.88 cm$^3$ volume and a 1.57cm depth were derived, as shown in Table 1.

**Table 1**. Depth and volume.

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| STRIPE | PIXELS |
|---|---|
| 7 | 370 |
| 8 | 719 |
| 9 | 962 |
| 10 | 1461 |
| 11 | 1720 |
| 12 | 1875 |
| 13 | 1988 |
| 14 | 2100 |
| 15 | 1897 |
| 16 | 1920 |
| 17 | 1624 |
| 18 | 1640 |
| 19 | 1214 |
| 20 | 772 |
| 21 | 594 |
| 22 | 360 |

MAX PROF = 1.57 cm

CAVITY VOL = 45.88 cubic cm

## 5 Discussion

The volume calculated by the program exceeds 6.7% actual measurement. The depth calculated by the program exceeds 12.1% actual measurement. The model cavity has a continuous surface. While the first difference can be considered satisfactory for m, the second one is too high and suggests some investigation to find possible causes.

In order to perform a new validation of the technique and eventually to achieve smaller differences the technique should be tested in a cavity model that allows a more confident volume measuring in comparison with glass mass filling. Improvement of software portability requires tests using other images and program adjustments as well.

## 6 Conclusions

The technique can be made suitable for evaluation of PU features in actual lighting environments. This encourages their use in clinical practice as an aid to health professionals. The $352 total cost for camera and illuminating device can motivate their large scale use.

The technique is able to provide depth in all well-defined positions belonging to the stripe shadows. So it satisfies Geoprocessing System requirements no matter the image domain. Supposed a huge amount of PU images is available it is possible to identify PU clusters and mine some relation between size evolution and other patient features. A similar study concerning urban expansion is presented in [16].

Using of images as similar as possible to a real PU is recommended as well as designing of additional image processing filters that generate images whose characteristics could be computationally measured.

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