A NEW STRUCTURED LIGHT METHOD FOR 3-D WOUND MEASUREMENT

Cengizhan Ozturk MD*†, Stephen Dubin VMD PhD*,
Mark E. Schafer PhD**, Wen-Yao Shi MD*, Min-Chih Chou*

†Imaging and Computer Vision Center, Drexel University, Philadelphia, PA 19104
* Biomedical Engineering & Science Institute, Drexel University, Philadelphia, PA 19104
** Sonic Technologies Inc., Hatboro PA 19140

Abstract

Our objective is to develop a flexible, non-invasive 3-D wound surface reconstruction system which can be used to evaluate physical characteristics, such as perimeter, area, depth and volume of wounds. We describe here our system which relies on a new temporal structured light (SL) coding method using a LCD projection system. In SL, the scene is illuminated with a pattern of light and is observed from another vantage point. Analysis of this image gives the 3-D surface points after establishing correspondence and triangulation. We report on initial performance tests of this system on phantoms and compared the results to physical measurements and saline infusion method. A sample pig skin wound reconstruction is also given.

INTRODUCTION

To evaluate new wound therapies, quantitative methods to characterize the rate of wound healing are essential. A number of methods have been previously described:

2-D methods (dimensions, area, perimeter):
- Caliper and other measurement devices [1]
- Tracing and measurement by weighting the material, scanning and image processing or by specifically designed tracing equipment [2,3]
- Photographs with scales

3-D methods (volume, complete reconstruction):
- Saline infusion [7]
- Casting [4]
- Stereophotography. [5]
- Structured Light [6,7]

METHOD

Our system consist of an LCD projection system and a CCD camera. The camera output is fed to a Macintosh Quadra 840AV equipped with a video acquisition board (Fig. 1). Temporal slides on the LCD are generated using perfect submap codes [8]. Once the images are acquired, the image processing goes through the following steps:

- finding the centroids on the sample and indexing slides
- labeling each sample point by it's temporal index
- finding each sample point's and it's 8 neighbor's temporal index and identifying the 3x3 windows
- establishing the correspondence
- triangulation to find the 3-D points
- rotating and gridding the data for display and surface fit
- conversion to a range image and segmenting the wound
- Finding the area, volume and other desired physical properties

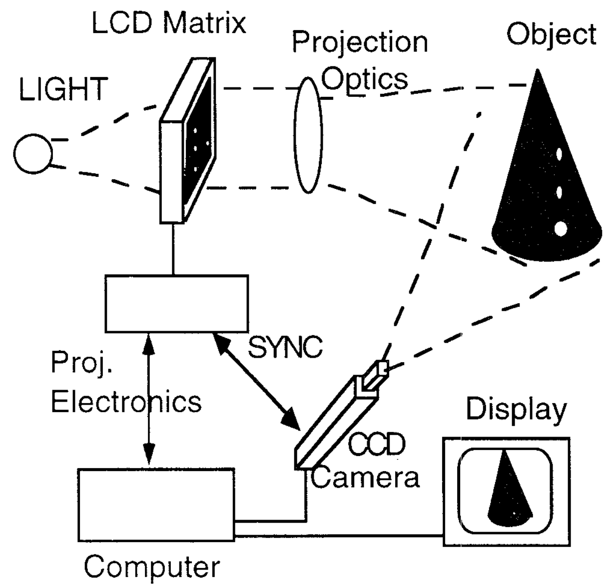

Figure 1: The system setup

RESULTS

5 wound models, with diameters 15-25 mm and depth of 4-10 mm, (2 cylindrical, 3 irregular cavities) were examined using 3 methods: Manual measurement, saline infusion and SL. In the first method, the major and minor axis of the phantom wounds and their depth were measured with an electronic caliper. The volume was calculated using a simple geometrical approximation of the cavity. The manual volume calculations showed good repeatability for the same experimenter: 3.4- 12.2%, but high variability between persons: 8.3-42.7%. The most significant factor causing this difference was in the depth measurement.

In the saline infusion method, the wound was filled until it was even with the cavity top surface. The volume in the syringe is measured by weighting before and after the infusion using a sensitive scale. Saline injection technique showed significant variations (2.4 - 17.1%) even for the same experimenter. The variability among different examiners ranged between 11- 27%. The variation was observed to be greater when the surface area was larger than base area and when the wound is irregular.

SL results showed high repeatability (<10%) and gave best results when sides of the wounds are not steep. This is the situation when the other 2 methods showed significant

0-7803-3204-0/96$05.00©1996IEEE

repeatability problems. In clinical settings this is also the most commonly encountered scenario. The average wound volumes of all methods are given in table 1.

	MEASURE	SALINE	SL
Model 1	1.64	1.22	1.03
Model 2	1.41	1.28	1.08
Model 3	2.61	2.01	1.70
Model 4	2.86	1.75	1.60
Model 5	1.37	0.94	0.90

Table 1: Comparison of volumes of 3 methods (cm^3)

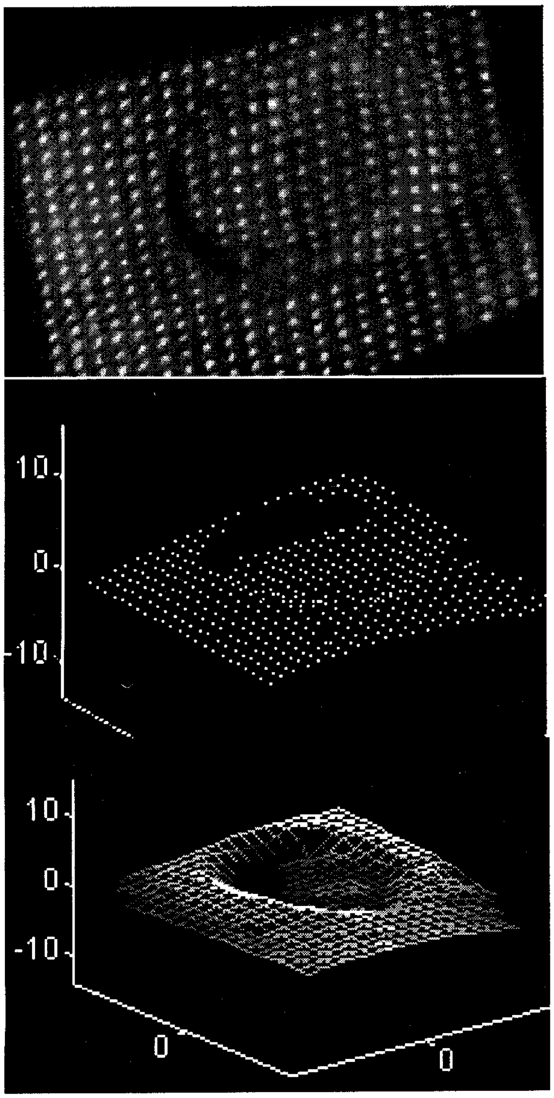

Figure 2: A wound image, 3-D points and reconstruction

Currently our system is being tested also in the full thickness pig skin wounds. Complete automatic reconstruction is not achieved yet because not enough points could be identified on the wound base, due to our current inferior optical system. 3-D reconstruction using supervised correspondence, however, could still be accomplished and an example is shown in Fig. 2.

DISCUSSION

We previously used a color SL system with a slide projector for wounds.[9] Color acquisition requires a more expensive setup and makes the image processing more complicated. Our new setup has several additional advantages:

1. It is possible to switch between different pattern types without the need for recalibration.
2. One can change the size of the dots individually or collectively for a given object
3. One can change the characteristics of the code (e.g.: hamming distance) adaptively depending on the outcome of the system.

The saline drip technique involves infusion of serum physiologic until the wound is filled. Convexity of the surface, leakage, pain are some of the problems of this method. Additional physical measurements are often required since the method only provides volume information.

In an previous SL application on wound measurement [6], similarly a customized camera with an illuminator was used. On the other hand, it projected a grid pattern. An operator, then, labeled the intersection points manually. Additional cameras would be needed to see the points which are not visible on the first camera and to help solve the ambiguity problem when part of the projection grid was occluded .

Our approach has the potential of working in partially occluded conditions and it also uses less acquisition time than the corresponding binary coding systems.

REFERENCES

[1] Kundin J. "A New Way to Size up a Wouund." American Journal of Nursing, 89 (suppl): 206-207, 1989.

[2] Bohannon R, Pfaller B. "Documentation of Wound Surface Area from Tracings of Wound Perimeters", Physiccal Therapy 63(10): 1622-24,1983.

[3] Frantz RA. "Film Scanner Used to Study Pressure Ulcers". Medical Electronics, February: 72-73, 1994.

[4] Covington JS, Griffin JW, Mendius RK, Tooms RE, Clift JK, "Measurement of Pressure Ulcer Volume Using Dental Impression Materials: Suggestion from the Field". Physical Therapy 60 (8): 690-694, 1989.

[5] Eriksson G, Eklund A, Torlegard K, Dauphin E. "Evaluation of Leg Ulcers Treatment with Stereo Photogrammetry", British Journal of Dermatology 101, : 123-131, 1979.

[6] Plassmann P, Melhuish JM, Harding KG. "Methods of Measuring Wound Size, A Comperative Study", Wounds 6(2) : 54-61,1994.

[7] Plassmann P, Jones BF. "Measuring Leg Ulcers by Colour-coded SL", Journal of Wound Care; 1 (3): 35-38, 1992.

[8] Ozturk C, Nissanov J, Dubin S, "Generation Of Perfect Map Codes For An Active Stereo Imaging System", Proc. of 22nd Annual Northeast Bioeng. Conf., New Brunswick,NJ, Mrach 14-15, 1996.

[9] Ozturk C, Nissanov J, Dubin S, Shi WY, Nichols J, Mark R, "Measurement of Wound Healing by Image Analysis", Proc.s of 32nd Annual Rocky Mountain Bioengineering Symposium, Denver, Co, April 7-9, 1995.