Quantitative Evaluation of Burn Scars

Sudeep Sarkar, PhD.

Computer Science and Engineering

University of South Florida, Tampa
Goal

- Goal is to formulate objective criteria for burn scar evaluation in terms of physical characteristics
  - scar elasticity
  - scar color and texture
- Presently physicians use subjective evaluations of the physical properties recorded on the Vancouver Rating Scale
  - experts rate physical aspects of a scar on integer scales
  - has low inter-rater and intra-rater reliability
Clinical Significance

- The objective measures can be used to objectively monitor the progress of burn scar treatment procedures
  - Present subjective scale is too coarse and unreliable
- These objective measures can also be used to plan treatment interventions.
- The developed Finite Element Models can be used to study the effect of burn scar on joint functioning.
Magnitude of the burn problem

- Each year more than one-million people suffer burn injuries in Canada and the US. About 60,000 of these injuries require hospitalization
- More than 35% of those suffering from burn injuries and death are children
- Fires and burns are the second leading cause of accidental death among children 1 to 4 years old and
- Third leading cause of injury and death among those under age 19
- More than 6,000 people die from fire and burn injuries each year
Input Data Set

3D Range Data

3D Range with Color
Measuring Scar (Relative) Elasticity

• Need an in-vivo technique to measure the progress of scar elasticity
  – relative estimates (w.r.t normal skin) suffice

• We use visible wavelength images along with 3D range images

• Stretching of scar tissue will be different from normal skin

• Given the observed stretch, we infer the differences in the underlying material properties
Methodology

- We mark (stamp) a grid on the scar
- We stretch the marked area by pulling near it
Methodology (contd.)

- We obtain range images of the marked area before and after pulling

(Distance from camera is encoded as intensity)

- We build a Finite Element Model (FEM) of the grid portion of the skin

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Theory

- The grid intersections act as key points whose movements are observed.
  - The grid and the intersection points are automatically detected by fitting “snakes” or active contours.
- Given the observed motion of the keypoints, known boundary conditions, and some initial estimates of the skin elasticity, we iteratively infer elasticity differences.
FEM Parameters

- Stress-strain behavior of skin under normal physiological conditions is modeled as being linear.
- We do allow for geometric non-linearities in terms of large displacements.
- The finite elements in the model are thin elastic structural 3D shells.
- Number of nodes in the FEM is around 360.
Locating the scar tissue

- Assuming normal skin elasticity properties, we first estimate the dense displacements of all the finite element nodes.
- Differences in strain distributions are used to infer local of elasticity differences
  - low strain areas (dark blue) correspond to abnormalities
Estimating relative scar elasticity

- Fix the displacements computed for the scar boundary
- Vary the Young’s modulus of the scar region
- Compute error between FEM predicted and observed displacements
- Repeat above two steps until error in a minimum

Displacement error behavior
Some results

- Outlined scar region
- Scar region identified as region of low strain (dark blue)
Results (contd.)

- Outlined scar region
- Scar region identified as region of low strain (dark blue)
Correlation with Expert Estimates

![Graph showing correlation between Expert Judgement of Elasticity and Program Estimate of Elasticity]
Estimating Scar Color

• The observed color of skin is dependent on
  – illumination type
  – geometry of light source
  – response of film or camera
  – 3D shape of the skin surface
  – intrinsic skin spectral properties

• Comparing just photographs over time is not sufficient
  – need for correction
Color Estimation Overview

1. Color and Range Image
2. Normalize Camera Response
3. Estimate and correct for light source geometry
4. Identify Scar Regions (Segmentation)
5. Rate each region (Bayesian Classification)
6. Compute Features for color-texture
7. Rating for each region
Normalizing Camera Response

- The response of the Red, Green, and Blue channels of a camera are not uniform.
- We correct for the non-linearities in the response in an extra calibration step using standard color patches.
Modeling the illumination source

- We use a standard daylight lamp
- We empirically model the spatial variation of the incident illumination
  - amplitude varies proportional to the inverse of the distance
  - Angular variation is a Gaussian function.
Calibrating for Light Source Location

Specularities

The location of the specular reflections on the calibrating spheres help us estimate the light source 3D location
Scar Segmentation

- Identification of scar pixels in the image based on color
- Each pixel is composed of red, green, and blue.
- Find clusters of pixels in the RGB space
  - Principal Component Analysis
  - Realign color coordinates based on eigenvectors
  - Median Cut
Segmentation Results

Image Source: Textbook
Segmentation Results

Color image

Segmentation of scar into three regions

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Effect of Illumination Correction

Top: Corrected Image
Bottom: Original Image

Region segmentation results
Effect of Illumination Correction

Top: Corrected Image   Region segmentation results

Bottom: Original Image   Region segmentation results

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Effect of Illumination Correction

Raw Image

Scar Segmentation

Corrected Image
Color-Texture Classification

- Classified at 90% accuracy using a Bayesian classifier.
- Classification by color-texture features: Homogeneity, cluster-shade, cluster-prominence, and variance of hue.
Conclusions

• We can objectively access burn scar elasticity, color, and texture in-vivo and in a non-invasive from visible light 2D image and 3D range image using computer vision techniques

• Fundamental contributions (computer vision)
  – relative material property estimation technique from images using non-rigid FEM models
  – estimating light source location using specular spheres
Publications

Publications (contd.)

Other personnel on the project

- Dmitry Goldgof, PhD, Computer Science and Engineering, College of Engineering, USF

- P. S. Powers, MD, Dept. of Psychiatry, School of Medicine, USF.

- Wayne C. Cruse, MD, Dept. of Surgery and Director of Tampa Bay Regional Burn Center, Tampa General Hospital.

- Graduate Students
  - Leonid Tsap, PhD, graduated in March 99
  - Mark Powell, PhD candidate
  - Yong Zhang, PhD candidate
Future Directions

- Correlate the image based measurements with the underlying histology
  - Can we say something about the underlying elastin and collagen fiber arrangements from the image based measures?
  - Can we say something about the amount of melanin and blood in the scar from the color-texture measures?
- Evaluate the effectiveness of treatment intervention, such as pressure garments, using the computed measures.