Washington University in St. Louis
James McKelvey School of Engineering

A Novel Bandage System

Final Presentation

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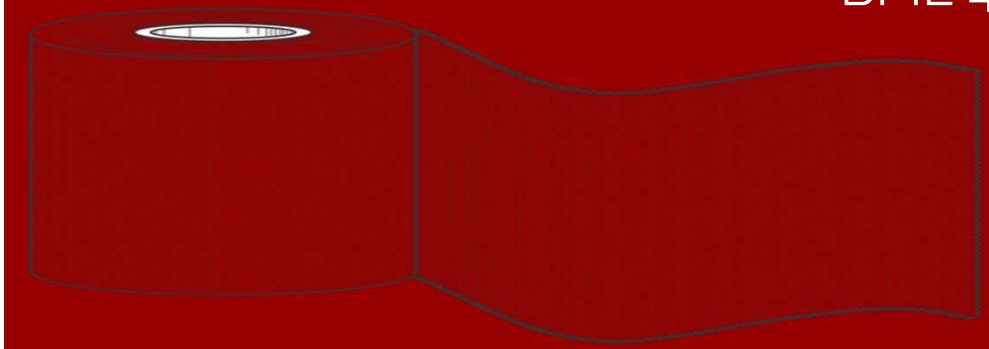
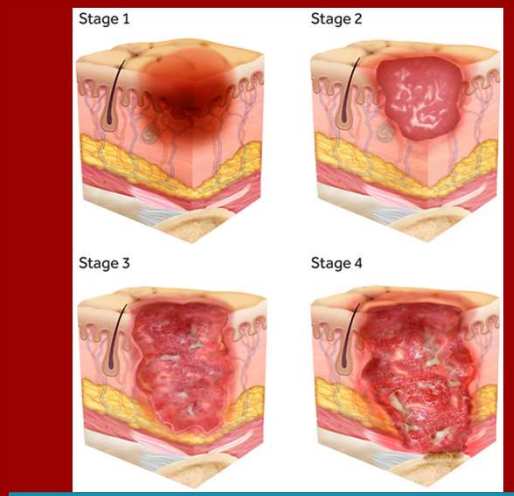
Group 15
BME 401A

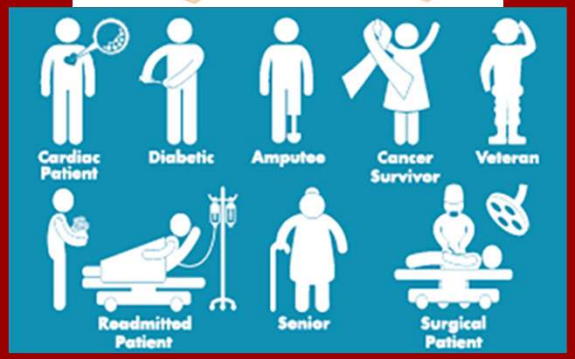


Background - Chronic Wounds

Over 6.5 million people in the U.S. have chronic wounds

- Ulcers: venous, diabetic foot, pressure, arterial insufficiency
- Pressure ulcers categorized into stage 1-4, unstageable, suspected deep tissue injury
- Impaired healing for over 4 weeks
- Costs U.S. healthcare system over $25 billion annually





De Moya et al. (n.d.), Robson and Barbul (2006), Grey et al. (2006), Zulkowski (n.d.)

Background - Wound Care

Chronic wound care is wasteful and costly

- 12 weeks follow-up: 30.5% diabetic foot ulcers, 29.6% pressure ulcers, and 44.1% venous ulcers healed
- Care given in outpatient departments, skilled nursing facilities, and home
- Global medical tape and bandage market valued at $7+ billion
- Manual fitting of bandages/dressings leads to wastefulness, imprecision, sterility concerns

Bauer (2016), Center for Medicare & Medicaid Services, Fife (2018), Grand View Research (2016)

Needs Statement

There is a need for a wound analysis and care system by clinicians to capture chronic stage 2-3 wound morphology and generate in a timely manner waste-reducing custom bandages to promote healing.

Project Scope

The group proposes to deliver a prototype of a system that can be easily used by clinicians for analyzing chronic stage 2-3 wounds and producing waste-reducing custom bandage templates. Clinicians currently tend to only use a fraction of larger bandages for wound care, and they would benefit from an optimized process reducing bandage waste when treating wounds of various profiles and complex contours. The first step of the process will require a portable imaging device that can be connected to a computer to record and save images of the wound in a digital file. Software will also be developed to analyze the wound from the images, quantify and model the interior surface of the wound, and generate an appropriate custom bandage template. Additional software is needed that can utilize the bandage template in a device that will execute the design and create a physical product embodying the size and shape of a custom bandage. By April 22, 2020 the project will be completed with an optimized process that successfully analyzes wound images and creates a schematic for a custom bandage design that can be carried out.

Chosen Solution - Overview

Imaging Device

- Multiple photos will be taken at different perspectives
  - 6-8 photos work best but a minimum of 2 photos

Structure from Motion (SfM) Analysis and Computation of the Boundary of a Binary Image Analysis

- Analyze visual documentation of wound in MATLAB app
- Provide 2 bandage templates

Chosen Solution - Overview

Laser Cutting

- Processed image data will be exported in a file format readily compatible with laser cutter
- Produce desired bandage shape based on template
- 100% cotton cut in place of bandage material for proof-of-concept

Hydrogen Peroxide Gas Plasma (HPGP) Sterilization

- Incorporate into production process
- Observe clinical sterility standards

Chosen Solution - Imaging Device

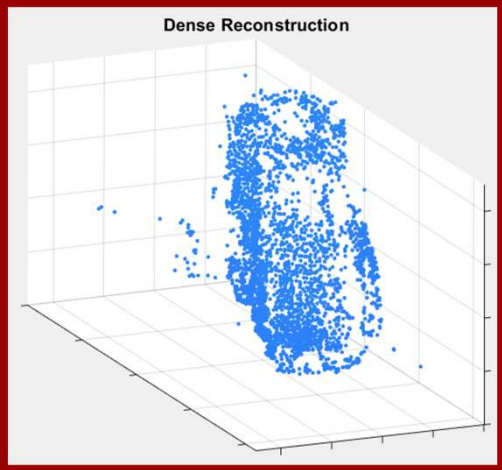
Phone Camera - Samsung Galaxy S8

- ***Unable to use point-and-shoot camera as planned because team member with wound models did not have access to point-and-shoot camera***
- Used to take 7 images of wound model from different perspectives
- Met image brightness and resolution design specifications

Chosen Solution - Wound Analysis

Structure from Motion (SfM) Analysis

- High resolution 3D reconstruction from 2D images
- Uses overlapping 2D images from multiple perspectives
- Automatically determines camera position and orientation
- Reference object needed to accurately determine sizing
- High accuracy
    - 1-5% surface area and volume relative error



Westoby et al. (2012), Yee et al. (2017), MathWorks (2019)

Chosen Solution - Wound Analysis

Computation of Boundary of a Binary Image

- Requires one image
- Converts color image into binary and finds image boundary
- Pixels in perimeters of objects of binary image are detected to compute perimeter of object in image
- Boundary dilated to conform to appropriate two-dimensional shape of the wound while increasing surface area

Chosen Solution - Production Method

Laser Cutting

- Focus laser beam to increase heat density at area of focus
- Cuts variety of material
  - E.g. cotton, nylon, metal
- Accurate
  - +/- 0.254mm
- Seals fabric edges
- Fast
- Compatible with pdf file format

Chosen Solution - Sterilization Method

Hydrogen Peroxide Gas Plasma (HPGP)

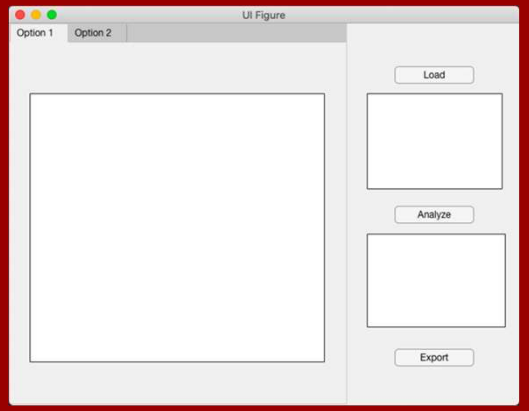
- Sterilization system
  - Disrupts biomolecules to inhibit metabolic and life functions
- Reduces damage to materials
  - No radiation
  - No heat, no moisture
- Non-toxic by-products
- May cause skin irritation

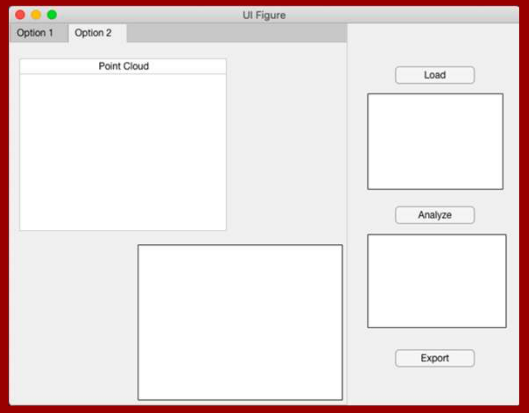
Centers for Disease Control, University of Rochester Medical Center, Bionics Scientific Technologies

Software Demonstration

User Interface - Graphical User Interfaces (GUI)

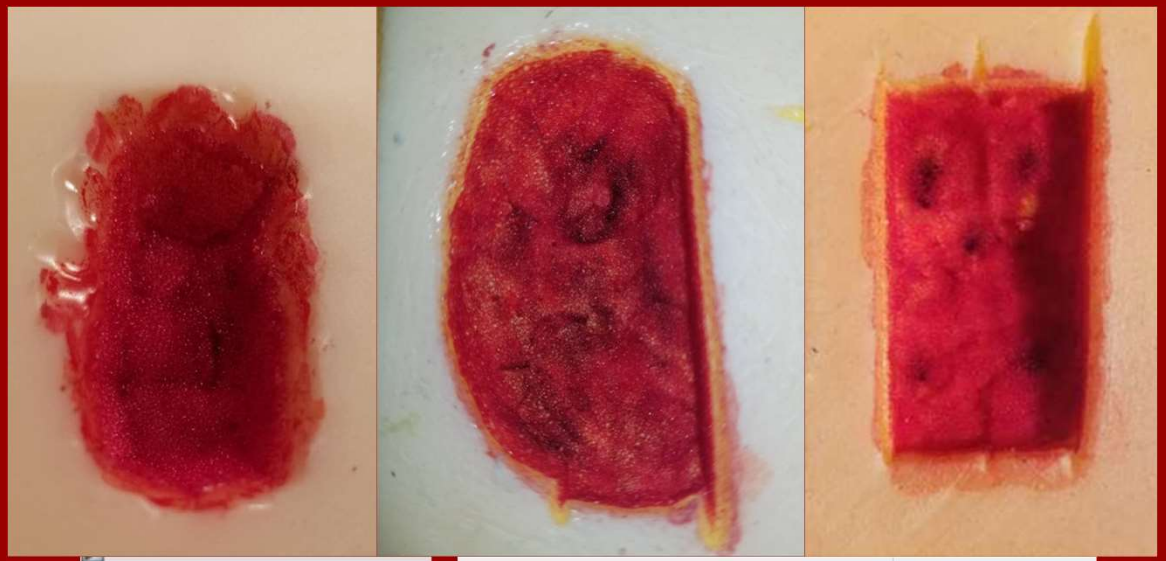
- Simple and straightforward
- Two options for different analyses
- 3 push buttons
  - Load
    - Enter patient name
    - Upload images folder
  - Analyze
    - Analysis algorithms run on wound images
  - Export
    - Template exported as pdf file
- Requires <30 minutes of training
- Requires English proficiency and basic computer literacy

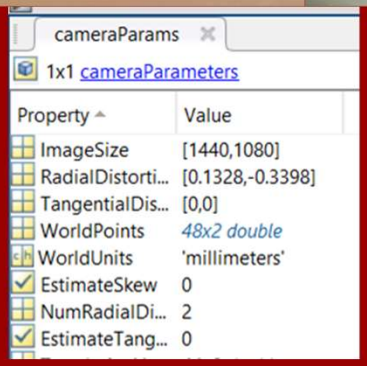


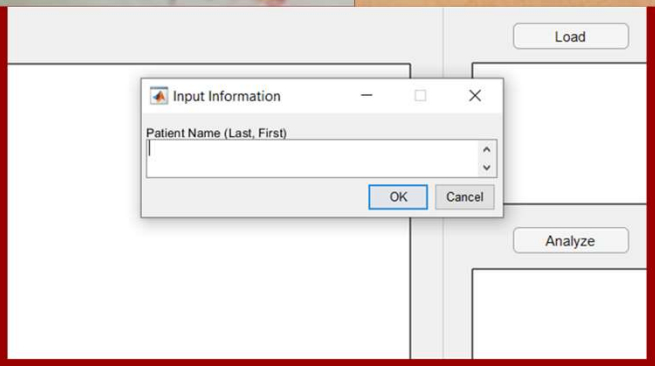


Input Data

- Wound images
  - Multiple perspectives
- Camera parameters
- Patient name

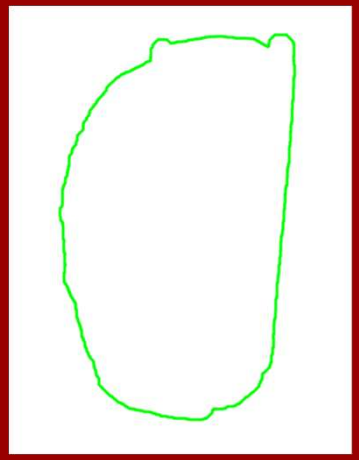


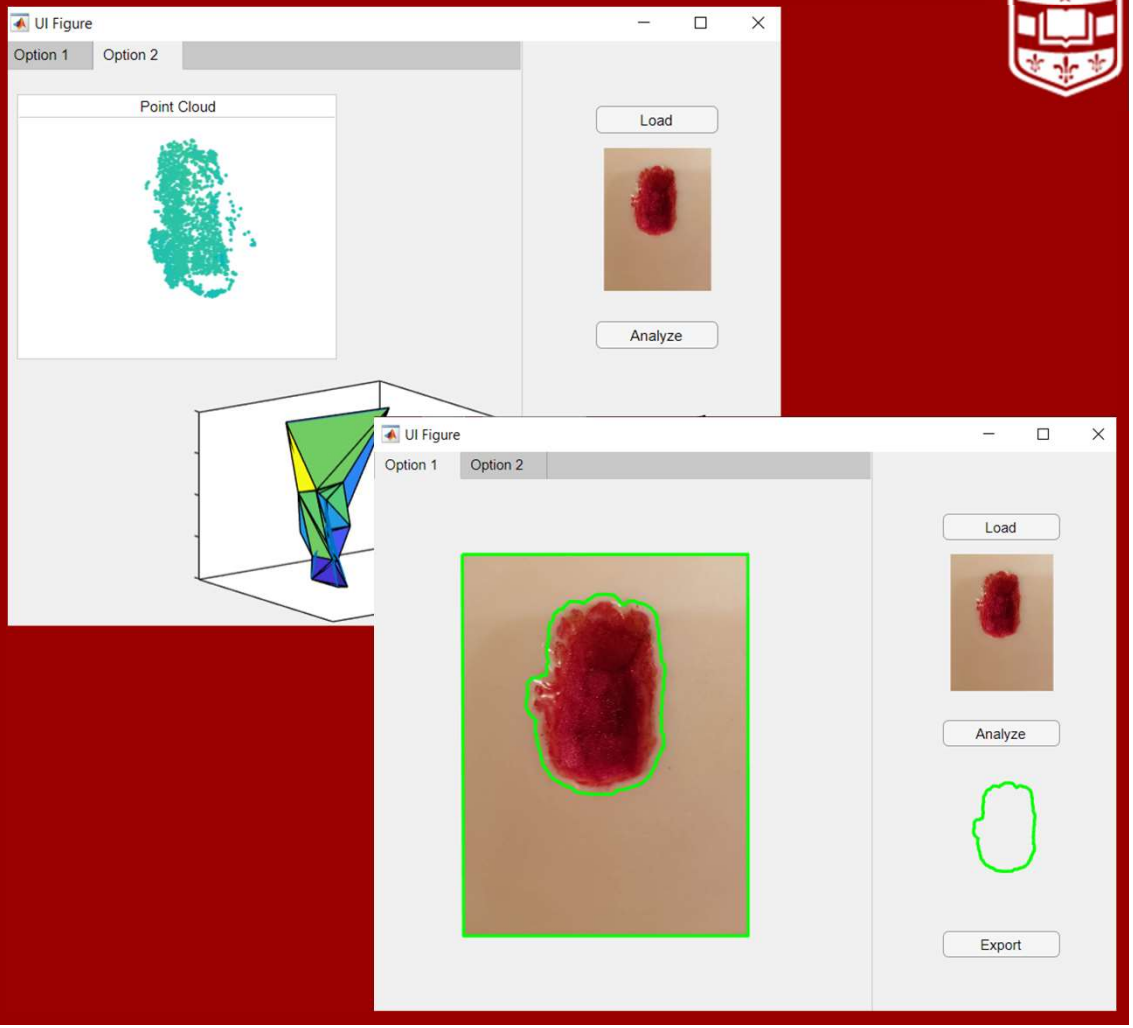




Output Data

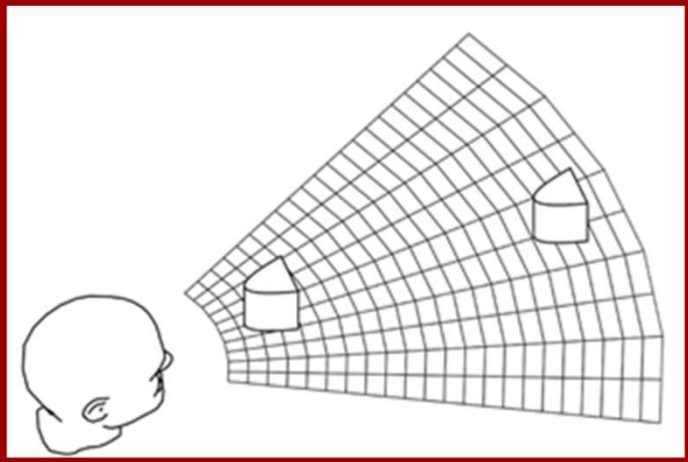
- Bandage template
  - Exported as pdf file
- Boundary of image
- Point cloud reconstruction





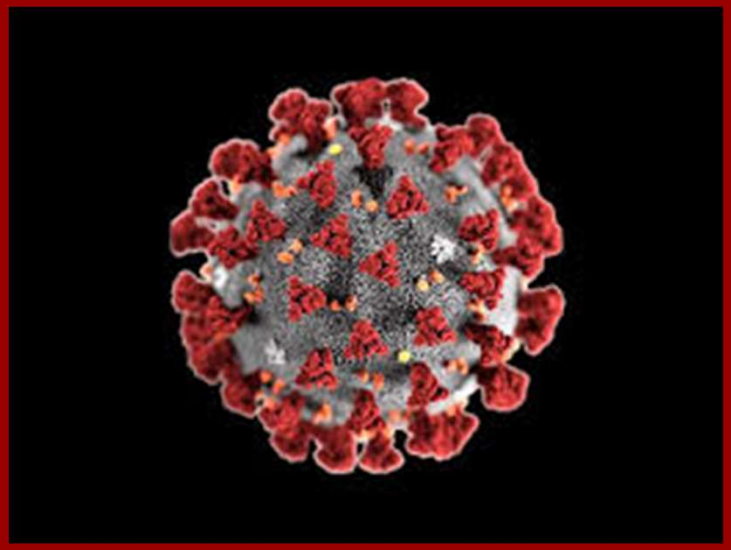
Likelihood of Success

- Major limitation is lack of successful implementation of visuospatial calibration
  - Quantitatively and qualitatively accurate templates
- Need to be able to test all components together to see if truly integrated



Impact of COVID-19 on Project

- Team meetings became virtual
- Team lost access to necessary equipment
  - Laser cutter
- Project materials were separated between group members
  - Required modification of solution
  - Required alternative testing of design specifications



Future Directions

Short-Term Goals

- Test integration of software, generated templates, and laser cutter
- Test measurement accuracy of software
  - Visuospatial calibration
  - 3D-printed wound models

Long-Term Goals

- Improve software algorithms especially sensitivity to fine detail
- Development of more templates

Lessons Learned

- Importance of careful software design, implementation, and enough time for integration
- Understanding of design process
- Practical experience developing the experimental process
  - Testing potential sources of error
- Need for cross-disciplinary collaboration

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