Project Proposal

Mixed Reality for Biopsy Site Localization

EN.601.456 Computer Integrated Surgery II

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Other team members:

Liam Wang, Biomedical Engineering Undergraduate Student (external to CIS II)

Dr. Peter Kazanzides: Research Professor, Department of Computer Science

Dr. Ashley Antony: Resident Doctor, Dermatology

Dr. Jeffrey Scott: Assistant Professor, Dermatology

Dr. Kristin Bibee: Assistant Professor, Dermatology

Dr. Elise Ng: Assistant Professor, Dermatology

1. Overview

Skin biopsies are used by dermatologists to diagnose cutaneous ailments, including tumors and rashes. However, if a surgery becomes necessary after a biopsy, determining the original site of the biopsy can be difficult due to various factors including the skin healing, biopsy depth, and background skin disease. This difficulty can lead to wrong site surgery, which is a never event — an error that is preventable and should never occur.

This project aims to create a mobile augmented reality application (to be deployed on a phone or tablet) that can register biopsy images to surgery images and subsequently overlay the biopsy site on live camera images taken by the mobile device. This would provide dermatologists with guidance sufficient to locate the biopsy site on the patient at the time of surgery.

2. Background

The usual procedure for biopsy site identification involves photographs of the biopsy site at the day of biopsy. While a lack of standardization is one of the factors that can make biopsy site identification more challenging [10], the Johns Hopkins Department of Dermatology has a typical procedure [12] that our application is intended to work with.

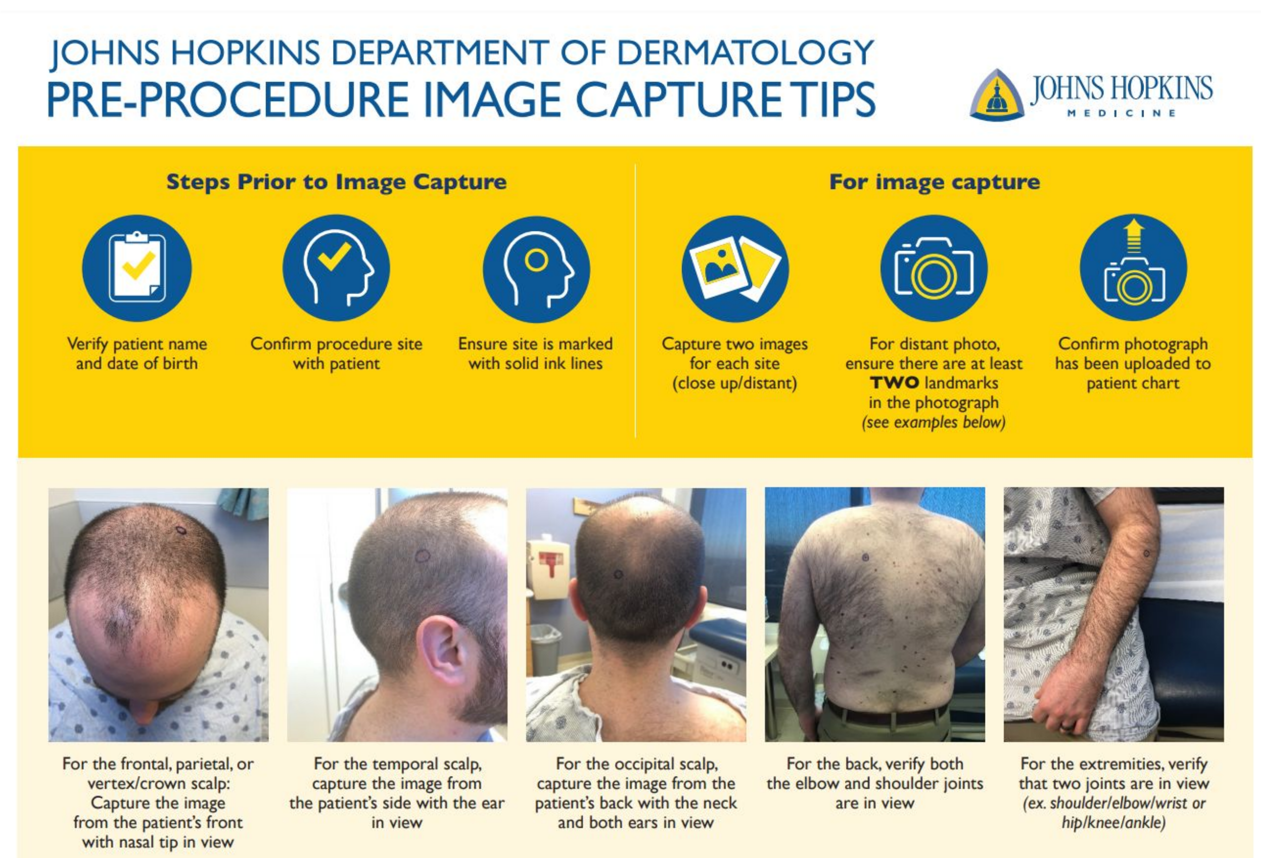

Fig. 2.1: Johns Hopkins Department of Dermatology pre-procedure image capture tips. Each capture of a biopsy site requires that the site is marked with a solid ink line, and that two images are taken: one close and one distant.

However, even with two photos, misidentifications can occur due to various factors.

Clinical Motivation

Wrong-site surgery, which can be a result of biopsy site misidentification, is a never event, a medical error that should never occur. However, in a study, physicians misidentified 5.9% of biopsy sites, and the surgeon and patient both misidentified 4.4% of the sites [11]. Despite the use of photography, biopsy site identification remains challenging.

If we are successful, the mobile application could be used by dermatologists to improve the accuracy of biopsy site localization, reducing the likelihood of incorrect site identification and thus reduce the number of or eliminate wrong-site surgeries resulting from biopsy site misidentification.

Prior Work

Others have attempted to address this need using various methods and tools, including a UV-fluorescent tattoo [2, 3], a transparent grid [4], confocal microscopy [5], “selfies” [6, 7, 8, 9], and facial recognition with augmented reality [10].

However, none of these have been incorporated into general practice yet, possibly due to cost, insufficient reliability, excessive disruption to the typical workflow, or concern of reaction from the patient (as is the case with a UV-fluorescent tattoo). Additionally, the existing augmented reality method using facial recognition does not provide a live image overlay and is only effective for biopsies on the face.

Goals

Our specific aim is to create a mobile augmented reality application, deployed on a phone or tablet, that can register biopsy images to surgery images and subsequently overlay the biopsy site on live camera images taken by the mobile device. We hope to provide handheld and convenient augmented reality image guidance that will allow the dermatologist to locate the biopsy site to about 5mm of accuracy, at which point they may be able to identify the biopsy site on their own.

3. User Workflow

Our intention is to create an application with the following UI workflow:

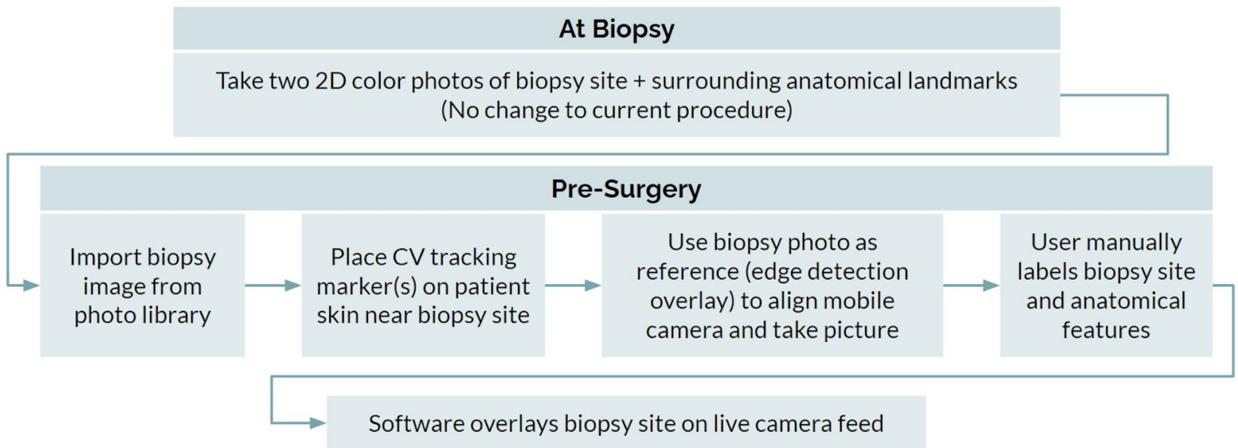

Fig 3.1: UI workflow. An overview of what we intend the user's experience of the application to be.

At the time of biopsy, the procedure does not change: the dermatologist will take two 2D color photos of the biopsy site, one close up and one at some distance so as to capture anatomical landmarks.

When the patient comes in for surgery, the dermatologist will import the biopsy image from their photo library on their mobile device. They will also place computer vision tracking markers on the patient near the biopsy site.

Then, the application will provide an edge overlay using the biopsy photo in order to assist in taking the surgery photo, so that the two images can be as similar as possible. The user will then manually label the biopsy site and anatomical features.

After that, the software will internally register the biopsy site to the markers and then overlay the biopsy site on the live camera feed.

4. Technical Approach

Broadly speaking, our application has three parts: the registration algorithm, the live marker tracking, and the mobile augmented reality application.

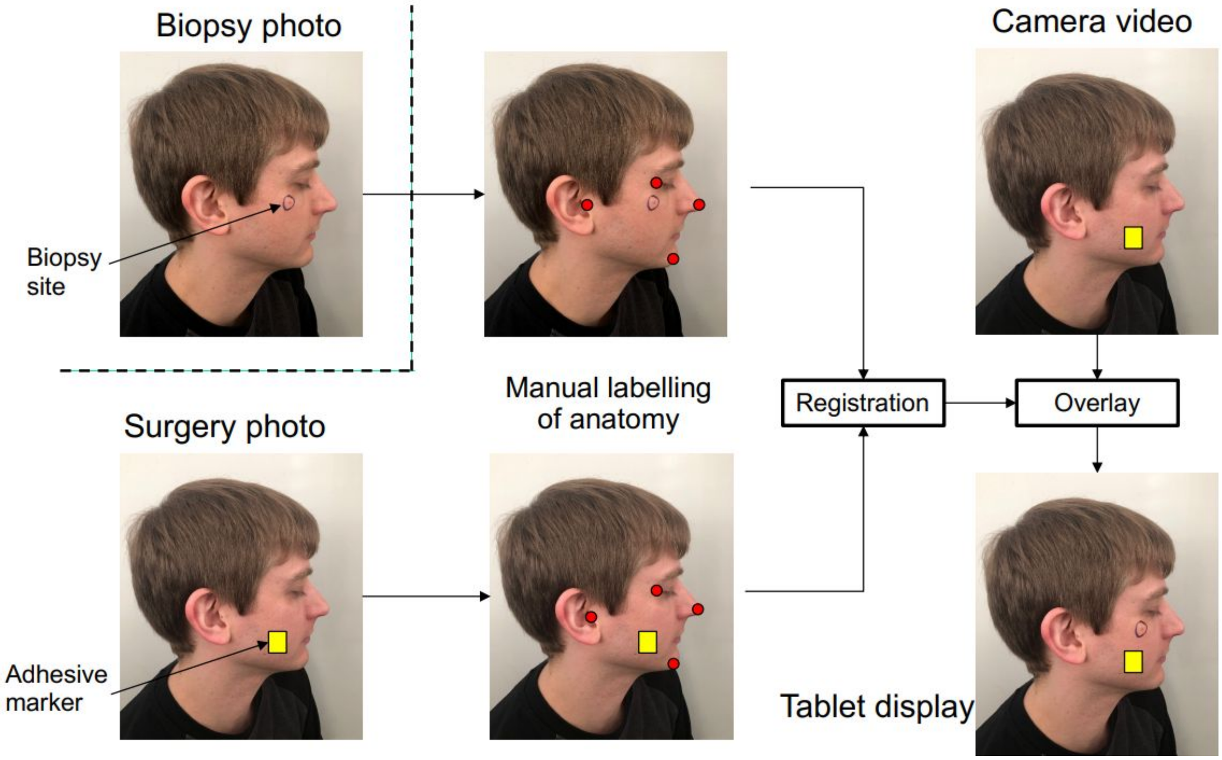

Fig. 4.1: A very basic overview of how the application will work. The user will have biopsy photos and surgery photos available, and will place tracking marker(s) on the patient. The user will manually label anatomical tracking points on the biopsy and surgery photos before the program registers the two photos, after which the program will provide a live overlay of the biopsy site.

Registration Algorithm

We will implement the registration algorithm using Python on Windows 10 with OpenCV packages. This can be prototyped with GRIP, an application typically used for rapid prototyping of computer vision algorithms.

The program will input user clicks as pixel coordinates in both biopsy and surgery photos for the biopsy site and tracking points. If the surgery and biopsy site photos are sufficiently similar, labeling on only one photo may be sufficient to reduce human inconsistency.

Feature detection, possibly corner detection, can be implemented to find precise tracking points near the input points. The program will then find a 2D-to-2D homographic transformation and create a circle or dot at the predicted biopsy site.

To test this, we can start by registering a biopsy photo to itself to check that the marked position is the same as the actual biopsy site position. Then, we can move on to testing our algorithm with proper photo pairs at various locations on the patient.

To interface this with the mobile application, we can export a data structure that can be read on both ends, such as a JSON that can store point correspondences, a descriptor, and information about the points of interest.

Live Marker Tracking

The live marker tracking will also be implemented with OpenCV packages. We have decided to use colored stickers as markers, which will be placed near the presumed biopsy location; we have four colors available.

The markers can be found using hue/saturation/value thresholding, and then their contours can be found and filtered so that they can be used to find the marker centroids. These centroid points will be used to calculate the 2D transformation of the biopsy site for each frame.

We can also calibrate for different lighting conditions - the dermatologist should take a picture from the live feed and select a marker, and the pixel color of the marker will be used to adjust the HSV threshold.

Fig. 4.2: The stickers we plan to use for live image tracking.

Application Development

For an XCode approach, we can create a Swift or Objective-C application with CocoaPods OpenCV dependency, using XCode storyboards and CocoaTouch for the UI layout. OpenCV also has an iOS library that we can use for live AR tracking and overlay within the app.

Alternatively, we may use Unity, which is better for cross-platform development — considering that XCode only works on Mac.

For integrating the mobile application with the registration and live marker tracking algorithms, we intend to use data structures that can be imported and exported from independent code, such as JSON or YAML. The data structure may contain information on the points such as the center and radius, or just the point.

5. Testing

We can test the efficacy of our application at various phases of the process.

With a functional desktop registration algorithm, we can determine the pixel accuracy of the biopsy site by registering biopsy images to themselves or to transformed versions of them and observing how far the predicted biopsy site is from the true site.

With a functional tracking algorithm, we can take a video (saved or live) of ourselves with a mark simulating the biopsy site and display where the program determines the biopsy is at. We can qualitatively assess the performance here, or quantitatively determine accuracy by locating the biopsy site in each frame with another method and calculating the distance in pixels.

With a functional application, we can do something similar to the testing for the tracking algorithm. However, we would also like for dermatologists to use the application in clinical situations or under conditions that simulate clinical situations. They may be able to provide information on the accuracy in real units as well as qualitative assessments on the user experience.

6. Deliverables

	Deliverable	Expected Completion
Min	Basic placeholder application	2/26
	Algorithm to register biopsy site photos to another photo / marked photos with documentation	3/5
Expected	Algorithm to track markers and overlay biopsy site to live video / video with tracking with documentation	4/2
	Error metrics to quantify accuracy of the live overlay	4/9
	Basic working interface with calibration overlay guidance with application documentation	4/2
Max	Completely functional mobile application with documentation	5/1
	Experimental data to quantify the geometric accuracy of our application	5/1

Fig 6.1: table of deliverables.

The key deliverables for this project are displayed in the table on the previous page, split into minimum, expected, and maximum deliverables.

Essentially, the very minimum, we intend to develop a skeleton for our application and project. We expect to have all the pieces for the application, and at maximum, we want to put everything together in a completely functional application.

Additionally, we intend to document our code to allow any programmer familiar with the art to run and possibly develop our code further. We will also develop error metrics to determine the accuracy of our application.

7. Dependencies

Our project has a few dependencies we need to address, which are indicated in the table below. We have also considered contingency plans for the cases in which the dependencies cannot be met, though most of them are already met.

Dependency	Need	Contingency	Status	Planned Deadline	Hard Deadline
Biopsy photos from Dr. Antony	For testing the registration algorithm	Photos of ourselves	Met	2/19	2/26
Computer/internet access	For software development and communication	If technical difficulties — repair or use alternate device. Internet — mobile data.	Currently met	Continuous	Continuous
Mobile device	For testing mobile application	Use mobile device software simulators	Currently met	Continuous	Continuous
Platform to develop application	Platform that isn't specific to iOS or Android and able to develop on Windows and MacOS	If not possible for technical reasons, use XCode (MacOS dev only)	Under consideration	2/26	3/5
Stickers	Markers for computer vision tracking	Print colored dots and tape them on	Met — Ruby has	3/1	3/15
Being able to load our application to an independent device	Independence would be useful for user testing, but iOS development restrictions may prevent easy deployment (may need a license or to stay plugged in to a computer)	Keep device plugged in, look for other methods of deployment, or buy license	Need to check	4/1	4/15

Fig 7.1: Table of dependencies.

8. Timeline and Milestones

The timeline of our project can be split into two sections: the registration and tracking, which Ruby will work on, and the mobile application development, which Liam will work on. The milestones are a slightly more detailed breakdown of the deliverables.

Registration and Tracking

Milestone	Expected Completion
Create basic I/O application to record user clicks on biopsy images	2/26
Finish algorithm to register biopsy site photos to another photo + documentation	3/5
Finish algorithm to track markers	3/15
Finish algorithm to overlay biopsy site to live video with marker + documentation	4/2
Quantify accuracy of the live overlay with pixel error metrics	4/9
Acquire experimental data and quantify errors in real units	5/1

Mobile Application Development

Milestone	Expected Completion
Create basic placeholder mobile application and determine how programs will interface	2/26
Create edge detection overlay for photography guidance and document code	3/5
Have a working UI to select points on images	3/15
Integrate photo registration and marker tracking into the mobile application	4/2
Complete and deploy final application with documentation	5/1

9. Team Members and Management

Students

- **Ruby Liu**
  Undergraduate student, Biomedical Engineering, Senior
  Responsible for the registration and live marker tracking software, as well as wiki upkeep.

- **Liam Wang**
  Undergraduate student, Biomedical Engineering, Freshman. External to CIS II
  Responsible for mobile application development.

Mentors

- **Dr. Peter Kazanzides**
  Research Professor, Computer Science
  Experience with mentoring CIS II projects, expertise in technical areas of the project.

- **Dr. Ashley Antony**
  Resident Doctor, Dermatology
  Clinical mentor familiar with procedures relevant to the project.

- **Dr. Jeffrey Scott**
  Assistant Professor, Dermatology

- **Dr. Kristin Bibee**
  Assistant Professor, Dermatology

- **Dr. Elise Ng**
  Assistant Professor, Dermatology

Ruby, Liam, and Dr. Kazanzides, with Dr. Antony and other dermatology professors joining when available and as needed, will have almost-weekly meetings to check in on progress and consult for any expertise.

Besides the meetings, we also have a Slack workspace where Ruby and Liam will keep in regular contact; Dr. Kazanzides and Dr. Antony are also in the Slack channel. The professors will also be available over email for any particular questions, concerns, or updates.

10. References

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