Project Livermore: 3D Simulation of Human Anatomy and Patient Education on Medical Conditions

Andrew Lam
Georgia Institute of Technology
Atlanta, GA, United States
alam3@gatech.edu

Cheryl Lockett
Georgia Institute of Technology
Austin, TX, United States
clockett6@gatech.edu

Jennifer Reina
Georgia Institute of Technology
Los Angeles, CA, United States
jreina3@gatech.edu

Rafay Syed
Georgia Institute of Technology
Roswell, GA, United States
rsyed8@gatech.edu

ABSTRACT

Project Livermore is a development project intended to address the issue of providing patients with timely and engaging personalized educational materials consistent with a diagnosis they may have received. This paper is intended to demonstrate a proof-of-concept tool to facilitate the dissemination of educational materials by way of a standards-based inter-operable tool whereby a patient is able to observe and manipulate a 3D model based on their diagnosis, observe disease progression, and read supporting literature. The tool is designed around a problem-based learning pedagogy that uses simulation-based learning to promote understanding.

Author Keywords

Patient medical education; Liver anatomy; Health Informatics; Treatment outcomes, 3D applications; Educational technology; Problem-based pedagogy; simulation-based education; Care provider delivery of education.

INTRODUCTION

Project Livermore was ideated out of the experience of a patient receiving a diagnosis for a condition, but not receiving sufficient educational materials about the condition. Significant quantities of health education materials are available on and off of the internet, but these can be confusing or contradictory at times. Additionally,

patients may get some information and instructions on subsequent treatments from the physician but may forget much of the information provided. This project explores options for satisfying the need for improved and personalized patient education in order to improve patient care outcomes. It implements a problem-based learning pedagogy as it is applied to the physician-patient team in pursuit of educating the patient and this collaboration is supported with simulation-based learning for the patient's disease.

PROJECT MOTIVATION

Easy and immediate communication is a staple of our hyperconnected era, where reaching out to others is only a couple of taps or clicks away and information is widely available and easily accessible. Despite this, patient healthcare education remains a weakness of healthcare globally. In the United States, for example, a typical scenario once a medical condition has been diagnosed is for the physician to request the patient to schedule a follow-up visit to discuss treatment options with a relatively small amount of time devoted to patient education. Instead, patients may be encouraged to call a phone line dedicated to medical inquiries or simply left without sufficient options to properly understand their condition and what to expect next.

To fill this gap, the patient may resort to searching for health information independently, most frequently through the internet on sites such as WebMD [18] or on online forums. These may provide some information about particular conditions, symptoms, treatments, and sometimes pictures, but may also provide questionable information that may result in a patient's incorrect understanding of their condition and compromise the effectiveness of the partnership between the patient and doctor through the treatment process.

The medical community has established the importance of the need for patient education to improve the outcomes of patient conditions and their treatments. Chapter 1 in

"Patient Education in Rehabilitation" outlines the benefits of patient education: "Specific interventions aimed at increasing the patient's knowledge can improve the treatment outcomes of many acute and chronic illnesses" [6]. Challenges in the delivery of effective patient education include the patient's difficulty in finding quality patient education resources, a lack of healthcare providers providing the patient education as part of their practice [15] due to many reasons such as training, organizational imperatives, a physician-oriented culture, etc. [7], and the engagement between the patient and educational materials provided.

Project Livermore aims to use educational technology techniques to demonstrate a solution that encourages patient education by leveraging 3D models featuring the liver to capture a patient's attention and interest in learning more about their own body. This visual approach can allow the patient to understand the differences between a healthy liver and a diseased one, even if symptoms may not be apparent externally. The project leverages ideas from visual and simulation-based learning to provide visual cues that stimulate a patient's interest in exploring the 3D models and the textual information associated with them which will in turn improve their retention of the information they learn as noted in the Yang study [19]. This arrangement is the essence of problem-based learning where the problem to solve is the disease to understand and treat and the learning is facilitated by the 3D organ simulation and supportive disease literature.

An additional concept in Project Livermore intended to enhance the exploratory effect of 3D visualizations during the patient education process is the integration with Health Informatics Standards to provide personalized information. Standards such as the draft Fast Healthcare Interoperability Resources (FHIR) are on track for widespread adoption in the healthcare industry and will likely underpin Electronic Health Records (EHR) and their exchange. By using a patient user's EHR, the application could adapt accordingly to reflect the patient's health status and provide a personalized experience in the learning process. The patient's education process, at this point, would no longer be motivated by 3D imagery alone, but also on the desire to learn more about their medical conditions at a personal level.

RELATED EFFORT RESEARCH
Anatomical organ modeling is not a new endeavor and in fact many programs, digital or otherwise, exist to accommodate the need for patient education.

With regard to products that provide 3D medical education or the tools to provide it, a number of tools available provide interactive 3D components and some integrated educational models with descriptions including BioDigital [2] and 3DOrganon [13]. While these applications charge fees to use, free tools exist that provide encyclopedic descriptions and 3D models of various diseases such as the Anatomography BodyParts3D Project [5]. Hormone Health Network's 3D Patient Education [8] (also free) focuses on 3D visualization and education of the endocrine system. The products provide varying levels of support for patient education, but do not provide personalized patient education.

Market research discovered only a single product that provides personalized patient education that goes by the name WeIVU [9]. WeIVU presents education materials to the patient that have been curated by their physician. The application enables the physician to assemble static medical images and notes that are presented to the patient in order to explain concepts such as anatomy and surgical procedures. The resulting information is thoroughly personalized for the patient, but an important downside is a labor-intensive effort for the physician that could cause the tool's use to be something that is easily neglected over time.

PROJECT APPROACH
One of the issues in healthcare is in providing effective patient education to help patients manage their conditions, especially chronic diseases, in order to save lives and costs. There are some issues around adequate patient information. The materials that care providers provide to the patients may end up being confusing or may not be physician vetted if the patient uses the Internet to find information. Additionally, the physician may not provide sufficient information to the patient at all or the information may not be available. This project seeks to address some of these issues by making educational materials that can be made available within the physician workflow in an EHR, such as during charting sessions, so they can send a link to the patient that launches a web application containing engaging, interactive educational materials pertaining to the diagnosis the patient may have.

The project is constructed around problem-based learning aided by a simulation-based learning approach. It provides the knowledge and understanding component of the problem analysis phase of problem-based learning by providing the materials for education and treatment and also 3D simulations with supportive text for disease and disease progression awareness which facilitate understanding.

For this project, the team wanted to make the user interface very easy to use with minimal training required so patients can learn about different liver diseases easily. Since the team members for this project are also in Health Informatics, it designed a web application that would not only be used to retrieve data from the FHIR server, but also be used to educate patients on the different diseases of the liver. Initially, the team considered building simulators for multiple organs, but due to the limited time available, it focused the project on the liver.

According to Dr. Bushman of Ohio State University, visual cues help students remember information in greater detail since the brain is known to be an "image processor" [4]. The team wanted to approach this project in a way that would not only be visual but also interactive.

A survey was planned in order to get feedback on whether the project was an effective liver disease education tool.

PROJECT EXECUTION
The goals for the project include:

- Providing patient education
- Making it accessible
- Making it engaging
- Making it easily shared by physicians or care professionals.

The team selected a problem-based learning with simulation-based learning approach to address previously mentioned deficiencies in patient education.

Identification of Goals Met
The application meets the goal of providing patient education by providing an interactive and educational tool.

It meets the goal of making it accessible by creating a web user interface that can be accessed from virtually any computing device. It is simplified so it is easy to use and learn the material and the supportive materials start with basic information that progressively becomes more detailed.
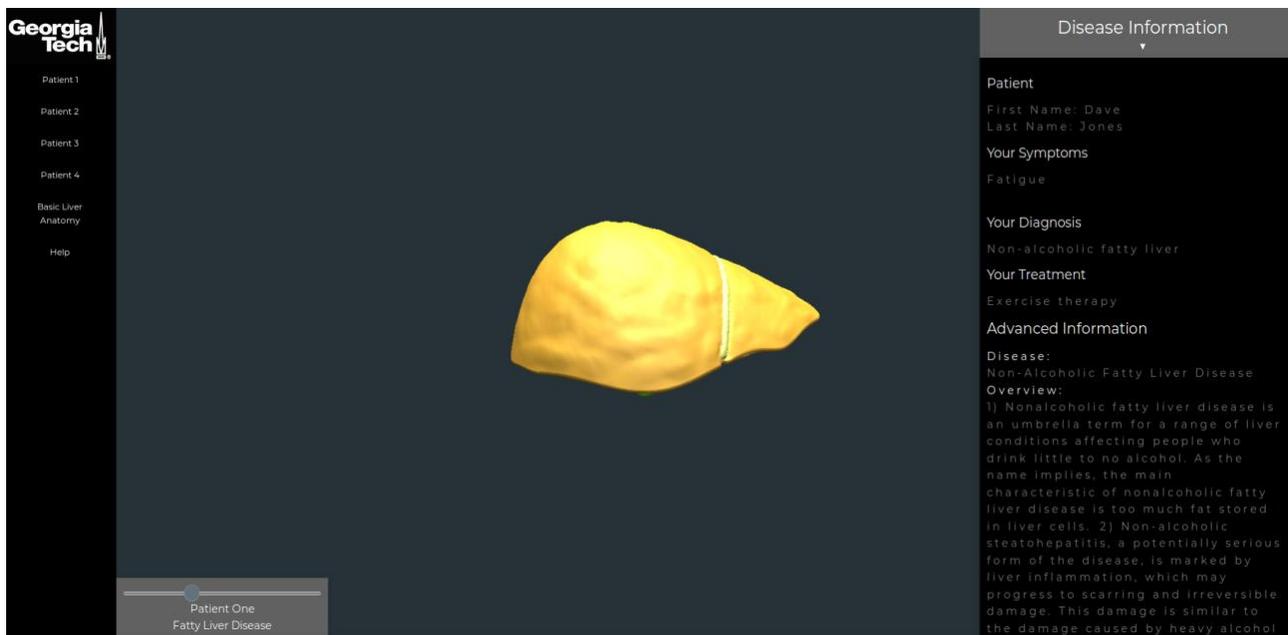
Figure 1. Project Livermore Web User Interface.

The goal of making it engaging is met by providing interactive 3D models paired with help pages for 1) understanding how to use the tool and 2) learning the basic anatomy of the liver (complete with labels).

Further interactivity is provided with a slider that updates the liver model with a visualization of the disease progression. The 3D model can be rotated and zoomed to be larger or smaller with the mouse. As for the slider, if treatment is followed, it shows a healthy liver (moving slider to the left), and if not, the next stages in the progression are presented (moving slider to the right). A couple of the mock patients have simulations of the progressions of their disease - with and without treatment - from healthy to increasingly worsening disease states.

The goal of making it easily shared by physicians or care professionals is met by making it a website that can be shared with the patient via the patient's EHR.

Visual Presentation
The user interface is intentionally simple for ease of use. It is split into 3 sections: a left panel contains a list of patients for demonstration purposes, a middle panel contains the liver model and slider for navigating disease progressions, and a right panel displays the personalized patient information. The right panel includes the diagnosis and treatment approach on the top and advanced disease educational information on the rest of the panel. The advanced information panel includes: disease name, overview of the disease, treatment, complications,

prevensions, and resources. This disease information is curated using data from the Mayo Clinic [12], a nonprofit medical practice and medical research group highly regarded as a leader in medical innovation and research as well as data from the American Liver Association [1]. This information allows the patient to be more aware of his or her disease and what steps could be taken to treat the disease.

Project Implementation

The application was implemented in a collection of docker containers. Each container provided a service. The services developed were as follows: the web user interface containing the patient portal, a MySQL database, FHIR connector service, and FHIR server.
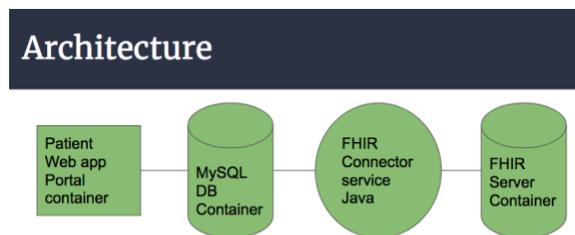

Figure 2. Project Livermore Architecture.

The patient portal was made with HTML, CSS, JavaScript, Blender [3], three.js [16], Flask, and Python. It also included starter liver models provided by the SketchFab website [14]. The MySQL DB Container included MySQL, bash scripts to load patient IDs and diseases into the database, and the file containing the disease educational materials that was loaded into the database. The liver disease educational materials were curated from the American Liver Foundation website [1]. The FHIR Connector container contained an application to read patient data from a local FHIR server and then load selected patient data (patient name, the disease, diagnosis and treatment) into the MySQL database. The application used Java and HAPI FHIR APIs [17]. The FHIR Connector container also contained an application that automatically loaded patient data into the FHIR server. This application used NodeJS and a FHIR JSON tag_loader tool. For the FHIR container the project used Daniel Johnson's FHIR server [10].

PROJECT RESULTS

While the team was able to meet most of the base features for the Proof-of-Concept application, there is significant room for improvement to make the application an even better tool for motivating patient self-education. Regardless, the team believes the application was able to meet the requirements needed to validate the assumptions in the proposal for this project.

To test this, the team created a survey to gather feedback on the application. This was shared on the class forums in Piazza and to coworkers, friends, and family of the team members for feedback on their experience. The survey consists of five questions: two of which rank the user's sentiments towards the application based on the team's assumptions and two requesting free form feedback on the concept and on improvements to the application. The last question is an optional open-ended feedback request:

1. *How effective were the 3D models in keeping you engaged and curious about learning more about the Liver diseases?*
2. *Think of a recent visit to your doctor. How informative is the disease information and the interaction with the application in comparison?*
3. *What do you think about the idea behind this Proof of Concept?*
4. *What suggestions can you offer to improve the effectiveness of this application?*
5. *Do you have any other feedback on this application?*

As a soft introduction to the project, the following summary was included:

> *"Hi! This is Project Livermore, a proof of concept application intended to showcase how 3D can be used to enhance and encourage patient self-education. In contrast to most 3D anatomy programs that display the human anatomy, some of which display static information about each body part, this application is instead focused on retrieving real patient data using the FHIR standard for Electronic Health Records (EHR) and displaying the 3D models and educational data that fit the patient. In addition to showing information on the patient's current health status, the patient will be able to see future disease progression as well as healthier states.*
>
> *For this PoC, we focus on 3D models and conditions of the human liver. Please visit the following site, poke around a little (after some loading time), and let us know what you think!"*

The following feedback data was collected out of 31 responses received at the time of writing. For further feedback, the survey remains open and available [11].

For the first question, the survey received a majority of responses (29/31 or 93.5%) finding the 3D images as an effective way to keep the user engaged in learning. Two users (6.5%) found the 3D images to add no improvement in their engagement with the application:

How effective were the 3D models in keeping you engaged and curious about learning more about the Liver diseases?

Very effective	19
A little effective	10
Neither effective nor ineffective	2
A little ineffective	0
Very ineffective	0

Table 1. Distribution of user sentiment towards the effectiveness of 3D visuals in engaging their interest.

The two users who were neutral on the use of 3D also felt the application was on par in providing them knowledge about disease conditions as compared to a visit to their doctor. However, one of these users did acknowledge the usefulness of using 3D models as a visual aid during a hospital visit.

When comparing the usefulness of the application to a doctor's visit, there was more variation in opinions. Although the overall sentiment remains positive (71%), the distribution of responses highlights the need to improve the application's user experience in delivering health education:

Think of a recent visit to your doctor. How informative is the disease information and the interaction with the application in comparison?

Very informative	13
A little informative	9
About the same	7
Not as informative	2
Not very informative	0

Table 22. Distribution of user sentiment when comparing the educational usefulness of the tool to a doctor's visit.

From the free-form responses received, the majority of the users had a positive opinion of the idea and could see benefits both in personal use and as a tool for physicians to help educate their patients. Out of 31 responses, three responses were neutral towards the concept and none have a negative opinion; however, one respondent questioned the likelihood of adoption of a tool like this by healthcare professionals and another respondent expressed concerns of scaring or shocking a patient with images of the human body in a diseased state.

The team also received many useful suggestions and constructive feedback on improving the idea further, with many feeling the proof of concept was sufficient at explaining the idea behind it. The three most common suggestions were:

1. Improving the performance of the application, particularly reducing the initial loading time.
2. Improving the User Interface and User Experience to be more intuitive, specially making it easier for elderly patients, computer illiterate patients, and patients with special needs to operate and navigate. A common suggestion was to add labels to the parts of the liver.
3. Adding enhancements to the 3D visualization aspect of the application, such as animated transitions between disease states and navigation into the internal structures of body organs.

Overall, the survey was able to confirm the usefulness of 3D technology in enhancing the patient education experience, with the opportunity for improving the usefulness of the application even further.

Project Presentation
https://drive.google.com/open?id=1BigLa3oMXHSvoGYaCdJrP-mirN-B52jB

CONCLUSION
There is a dire need for healthcare professionals to be able to communicate with patients in a transparent and understandable way in order to improve diagnosis and treatment outcomes. Project Livermore exists in a unique space addressing the need to bridge the communication gap between physicians and patients in a healthcare treatment setting. The project was a proof of concept to use problem-based learning pedagogy in introducing a personalized simulation-based learning tool using 3D organ simulations with supporting literature into the client-practitioner experience. The goals were to make it easy for the practitioner to share the educational information with the patient and to make the educational information available and engaging to the patient. The hope was to make the provider-patient collaboration more effective and improve treatment outcomes. Assuming the findings in the literature regarding the impact of patient education on outcomes, the initial project findings indicate that this style of patient

education can be an effective approach for improving outcomes in the course of medical treatments.

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