CIS II Project
Laboratory for Computational Sensing and Robotics
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CIS II Proposal

Title

Patch Ultrasound

Mentors

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Background

Ultrasound has been widely used in clinical practice for decades, but the devices used for diagnoses are usually huge. The first generation of ultrasound machines is cart ultrasound, which is clumsy and inconvenient to move. Later the Laptop Ultrasound and phone ultrasound came out. Even though they are much more portable, they still need the operator to hold the probe to detect the patient's body. Therefore, the project wants to build a new generation of medical ultrasound called patch ultrasound, which enables the operator to use both hands to focus more on their operations, reducing hand-eye coordination requirements during the operation.

Ultrasound is critical in many medical applications, such as fetal ultrasound measurement. It can show how the baby is growing and detect abnormalities, which is a significant step for testing the health of the mother and baby. However, during the whole pregnancy, mothers must take fetal ultrasound measurements multiple times by revisiting the exam room. The frequency of visits would increase a lot if the baby were in the wrong position, or the mother was obese. Such frequent revisiting would influence the efficiency of the exam room, and mothers could get uncomfortable during the trip to the hospital. Under the consideration of making mothers more comfortable when getting ultrasound measurements during the pregnancy, the patch ultrasound will include the feature of controlling remotely by the expert through a user interface (UI) so that mothers are not required to show up in the hospital to get the ultrasound measurement. Instead, they could enjoy the time staying at home while the measurement is done. Besides, patch ultrasound is structured much simpler than the traditional ultrasound machine, which reduces the cost of the device to a great extent.

Goal

The goal of this project is to build a patch ultrasound prototype that has the features of hand-free and tele sonography in Obstetrics and Gynecology (OB/GYN) applications.

Technical Approach

The user interface will be a web application, whose front end will be written using JavaScript and back end will be written using Python. The patch ultrasound itself will use an acoustic mirror to reflect sound waves coming from the transducer so that the operator could measure the patient from multiple angles. An acoustic mirror is a part that could reflect the ultrasound wave to a specific angle without losing too much energy, as shown in Figure 1. With the application of an acoustic mirror, the patch ultrasound could detect the target from multiple angles without moving the probe.

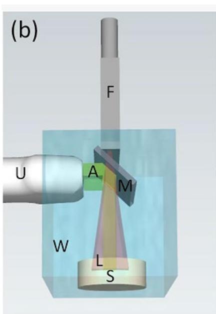

Figure 1. Example showing how an acoustic mirror works. [1]

Furthermore, a mechanical lock will be designed for the patch ultrasound in order to hold the probe and make the patch ultrasound wearable, which frees doctor's hands during the fetal measurement, enabling operator to work remotely. The communication between the patch ultrasound and the user interface will be accomplished through web socket. A block diagram shown in Figure 2 could help illustrate the technical approaches more clearly.

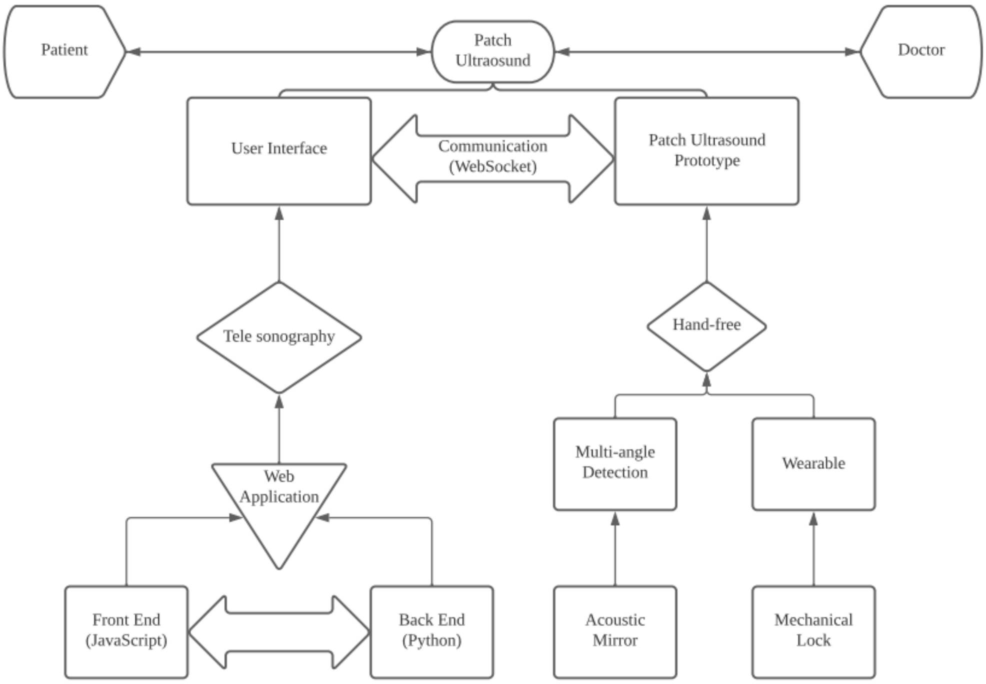

Figure 2. Technical approaches and their purpose

Deliverables

The deliverables for the project are listed in Table 1.

Table 1. List of deliverables

	Deliverables
Minimum	1. A web page showing real-time ultrasound images with buttons to move the ultrasound probe in a simulated system. 2. A conceptual mechanical design (mirror based) of the patch ultrasound. 3. A report on a phantom study of an acoustic mirror.
Expected	1. Demo the UI on a real patch ultrasound prototype. 2. Detailed manufactured design (CAD).
Maximum	1. A patient end interface. 2. A prototype to demonstrate the feasibility of mirror-based patch ultrasound. 3. The communication between the prototype and the UI.

Milestones, Timelines, and Responsibilities

The milestones for this project along with the key dates for each milestone are summarized in Figure 1 in the Appendix section. The blue sections will be finished by Yuanwu He, and Shuran Zhang is responsible for the red sections. The green sections will be finished by both students together.

Dependencies

The dependencies along with the key dates for this project are shown in Table 2. The funding for purchasing products in this project will be provided by Dr. Boctor.

Table 2. A list of dependencies

Dependency	Solution	Alternative	Status	Due Dates	Effect on milestones if not met
Assembly parts (e.g., motors, mirrors, rods, etc.)	Purchasing from the internet	NA	Not started	4/24	1. The prototype could not be built. 2. Communication between the prototype and the UI could not be established.
3D Printing	3D printer at Homewood campus	Purchasing from the internet	Not Started	4/17	
The patch ultrasound simulator	Provided by Keshuai	No simulation	In progress	4/3	Hardware only
Acoustic Mirror	Purchase	Make a simple one	Not started	4/17	Create an innovative design without using an acoustic mirror
Ultrasound Machine and Probe	Dr. Boctor's lab has multiple devices	NA	Completed	NA	Run simulation instead

Management Plans

The management plans for this project are listed in Table 3.

Table 3. Management plans for this project

	Management plan
Project meeting with mentors	Every Monday from 1:00 p.m. to 3:00 p.m.
Team meeting	Every Monday and Friday for progress updates.

Daily communication	Microsoft Teams
Programming codes	Shared and stored through GitHub
CAD and documentation files	Uploaded to OneDrive

Reading List

[1] B. Jiang, K. Xu, R. H. Taylor, E. Graham, M. Unberath and E. M. Boctor, "Standard Plane Extraction From 3D Ultrasound With 6-DOF Deep Reinforcement Learning Agent," 2020 IEEE International Ultrasonics Symposium (IUS), 2020, pp. 1-4, doi: 10.1109/IUS46767.2020.9251555.

[2] Gueziri, H.-E., Santaguida, C., Collins, D.L.: The state-of-the-art in ultrasound-guided spine interventions. Medical Image Analysis 65, 101769 (2020)

[3] Hacihaliloglu, I., Rasoulian, A., Rohling, R.N., Abolmaesumi, P.: Statisticalshape model to 3D ultrasound registration for spine interventions using enhanced local phase features. In: International Conference on Medical Image Computing and Computer-Assisted Intervention, pp. 361–368 (2013). Springer

[4] Black, David; Yazdi, Yas Oloumi; Hadi Hosseinabadi, Amir Hossein; Salcudean, Septimiu (2021): Human Teleoperation - A Haptically Enabled Mixed Reality System for Teleultrasound. TechRxiv. Preprint. https://doi.org/10.36227/techrxiv.15175869.v1

Reference

[1]Wang, Y., Lim, R.S.A., Zhang, H. et al. Optimizing the light delivery of linear-array-based photoacoustic systems by double acoustic reflectors. Sci Rep 8, 13004 (2018). https://doi.org/10.1038/s41598-018-31430-5

Appendix

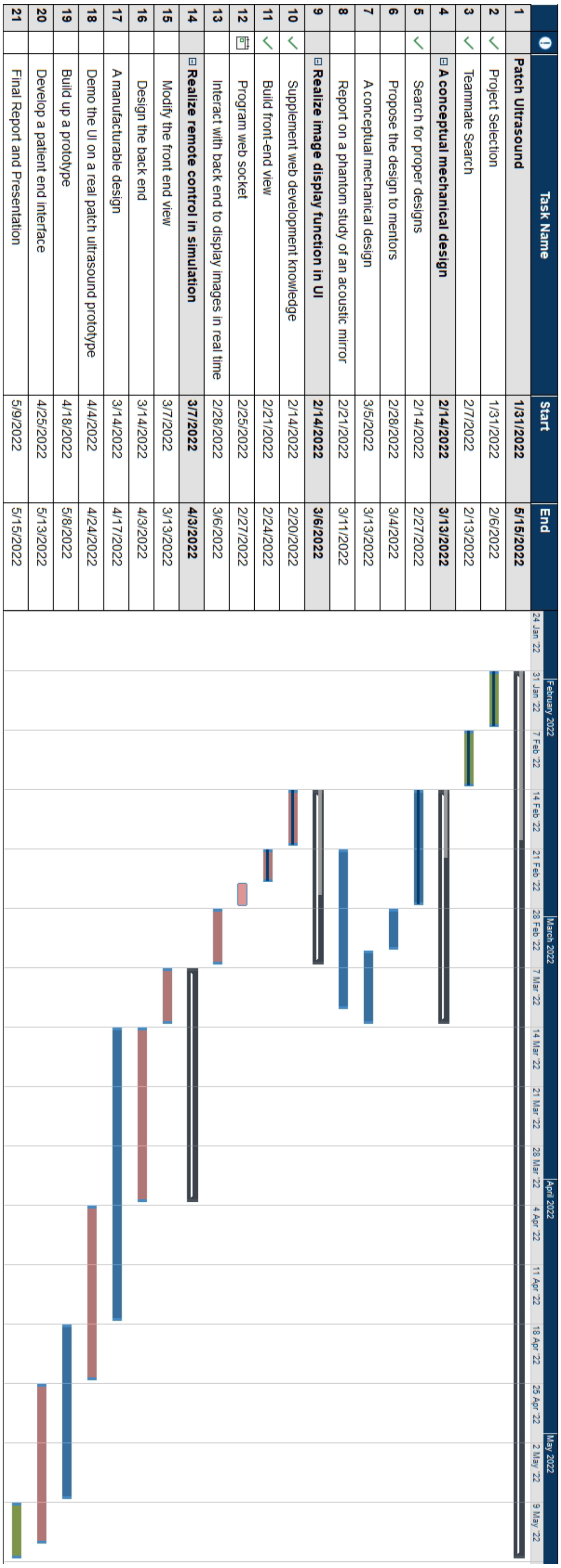

Figure 1. Timeline Gantt Chart