EE119/EE219 Final Projects 2025

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Students will work in teams of 2-4 to design an imaging system using one of the three sensors used in the lab. Students can choose between the three projects below and will be assigned hardware accordingly. Students may also submit a project proposal by May 10th if they would like to work on their own idea. These will be evaluated by course staff for approval. Independent projects will require students to be more self-sufficient and will have less support from course staff.

Important Dates

Deliverable	**Due Date**	**Location**
Project Sign up Form	11:59pm on May 16th, 2025	Gradescope
(optional) Independent Project Proposal	11:59pm on May 16th, 2025	Gradescope
Checkpoint	11:59pm on May 21st, 2025	Gradescope
10-15 Minute Demo	TBD, likely on June 3rd, 2025	Packard 057
Final Report	11:59pm on June 9th, 2025	Gradescope

Project Descriptions

Secure Face Detection with ToF Camera

Facial recognition systems using 2D cameras can be easily fooled by photos. Your iPhone uses 3D depth information from a LIDAR to guard against such attacks, and we can do similar with our 3D ToF camera. First you will use a standard face detection algorithm to detect whether a face is present based on a 2D image, and then you will analyze the 3D depth image to determine whether the detected face is real or fake. You should characterize the accuracy of your system under a variety of conditions such as different angles and distances from the camera. Your system should work on both prerecorded data as well as with real-time data from the ToF camera.

Materials

- LIPSEdge DL 3D ToF Camera (datasheet)
- A variety of faces and print-outs of faces

Tips

- You can use the built-in KLT algorithm in Matlab to detect a face in a 2D image.
- A variety of image segmentation algorithms can be used to isolate a region of interest, such as a face, from the rest of the image.
- The RGB sensor and the ToF sensor are slightly offset within the LIPSEdge module, and also have a slightly different field-of-view. How does this affect the alignment of their respective images?
- Think about what metrics can be used to distinguish the depth map of a real face vs a fake face. How can you make your classifier robust to different rotations and scales?
- The ToF camera can be set to “near mode” or “far mode”. Which parameters of the imaging system does this effect, and how does it affect the performance of the system?

Touchless Musical Instrument with Ultrasonic Sensors

A theremin is a musical instrument that allows the user to control frequency and amplitude of the output based on the distance of a person's hand from two receive antennas. In this project, we will use ultrasonic sensors to build a similar instrument. You will need to use at least two ultrasound transducers to control the frequency and amplitude of your generated audio. You should characterize the range and resolution for which you can control the musical notes in your system, and implement signal processing techniques for mitigating clutter and multipath to accurately isolate the response of both hands. You should be able to play a simple song (eg. Twinkle Twinkle Little Star) with your instrument and clearly show how your motion translates to the generated sounds in real time. You may expand upon the effects of your instrument by increasing the number of transducers to play multiple notes simultaneously, or add effects based on speed or received intensity.

Materials

- DK-CH201 ultrasonic development board with CH201 sensors
- Speakers or headphones
- Various reflecting targets

Tips

- To read A-scan data into Matlab in real-time, we will use the HelloChirp firmware. Instructions on how to flash this firmware can be found here.
    - Note that the HelloChirp firmware is not compatible with SonicLink, so you will need to reflash the default firmware whenever you want to use SonicLink.
- You can use the sound() function in Matlab to play a custom audio waveform.
    - The HelloChirp firmware will output A-scan data at a fixed repetition rate. You should set the duration of each note accordingly.
- Think about how your target material/shape/size affects the quality of your signal, and what signal processing techniques you can use to isolate the peak of interest.
- The MEASUREMENT_INTERVAL_MS parameter in the HelloChirp firmware controls how often the board performs an A-scan measurement. How does this parameter affect the responsivity of your instrument?
- The pitch of musical notes follows a logarithmic relationship with the frequency of sound, and this should be considered in how you control of your instrument.
- How does the field-of-view of the sensor affect the performance and usability of the system? How could you achieve a narrower field-of-view with the same sensor?

Through-Wall Imaging with mmWave Radar

In this project, teams will design a system to detect people behind a wall. The goal will be to count 1-3 people moving behind a wall at various distances and movement speeds. During the lab we used the mmWave Demo Visualizer with the basic mmWave board. In this project you will get access to the data capture adapter (DCA) which allows for much more configurability of the chirp signal and access to raw data from the sensor using mmWaveStudio software tool for offline processing. Data will be collected from the scene in the mmWaveStudio GUI and then analyzed afterwards offline to detect and track people within the scene.

Materials

- mmWave Radar Board, IWR6843ISK Evaluation Board, datasheet
- mmWave DCA1000EVM Data Capture Adapter (DCA), datasheet
- Wall obstruction (shared by students)

Tips

- For exploration, you can use the mmWave Demo Visualizer (User Guide).
    - Export and parse data using mmWave Demo Visualizer Parsing Script in SDK Package
        - Use script under packages -> ti -> demo -> parser_scripts called mmw_demo_example_script.py to explore point cloud data
- Your final project will be expected to use mmWaveStudio (User Guide) for greater configurability of the sensor and more advanced signal processing.
    - Software installation guide
    - Data parsing tools
- To track people successfully, the range-doppler information will need to be used to cluster data points together to detect people and more advanced algorithms will track between frames so that if a person stops moving or if two people are close together an accurate count is maintained, examples of the types of algorithms necessary can be found in the People counting TI application
- How does a person's walking speed and direction impact how well they can be detected? Can stationary targets be reliably detected?
- What are the limitations of separating between two targets? How can doppler information be used to expand this capability?
- What would be required to enable this application to operate in real-time?

Deliverables

Checkpoint (10% of grade), 11:59pm on May 21st, 2025

Complete 2 page report addressing the following, these sections may be reused in the final report:

Item	*ToF*	*Ultrasonic*	*Radar*
Theory of Sensor Operation Include specific values from the sensor datasheet to develop a theoretical model	Explain how depth map is derived from phase information, factors affecting measurement quality, tradeoff between maximum depth and depth resolution	Explain path of the acoustic wave, data acquisition, and signal processing to get A-scan data.	Address how chirp signals work and how doppler data is processed Discuss the radar equation and a target's RCS
Advantages and Disadvantages of Sensor Modality for Specific Application	Address impact of resolution, materials, ambient illumination	How the signal quality is affected by target properties, clutter	Address impact of materials, resolution, range
Preliminary Experimental Results	Collect data from a few different faces and printouts. Show face detection from RGB images, and plot 3D profile of faces from depth data.	Flash HelloChirp firmware with modified refresh rate, and plot real-time A-scan data in Matlab. Show preliminary results of peak detection and sound output.	Show successful data capture using the DCA and using code to output a range doppler plot for several time steps (do not just submit the DCA GUI output plots)

Project Demonstration and Q/A (60%)

Groups will sign up to demonstrate their project to the course staff and answer questions about their implementation.

Final Report (30%), 11:59pm on June 9th, 2025

Final Reports should be 3-5 pages and address the following topics:

Item	*ToF*	*Ultrasonic*	*Radar*
Theory of Sensor Operation Include specific values from the sensor datasheet to develop a theoretical model	Explain how depth map is derived from phase information, factors affecting measurement quality, tradeoff between maximum depth and depth resolution	Explain path of the acoustic wave, data acquisition, and signal processing to get A-scan data.	Address how chirp signals work and how doppler data is processed Discuss the radar equation and a target's RCS
Advantages and Disadvantages of Sensor Modality for Specific Application	Address impact of resolution, materials, ambient illumination	How the signal quality is affected by target properties, clutter	Address impact of materials, resolution, range
Experimental Results and Comparison to Theoretical Expectations	Classification results & accuracy, plots to demonstrate each step of algorithm, calculations for aligning images	Experimental results with different targets, explanation of physical design & signal processing approach	Complete experiments with different wall thickness and ranges with varying number of people, compare to expected link budget
How sensor parameters in datasheet relates to their results	XY resolution, depth resolution, max depth, FoV, wavelength	Range resolution, wavelength, sensor bandwidth, field of view, aperture size, baud rate	Range Resolution, angular resolution, doppler resolution
Limitations of System performance	Explain how limitations on depth resolution and max depth affect system performance	Explain limits of range, resolution, update rate. What factors limit the stability/quality of measurements?	Discuss what kind of scenes cannot be detected well and why
Potential Future Directions	Identification of different people, machine learning on depth data, IR heat map	2D/3D localization, beam focusing for enhanced directivity	Address potential advanced capabilities and their theoretical limitations