

Tactile Screen for Visual Aid

By

Walter Chang

Joshua Sluis

Tyler Wille

Project Proposal for ECE445, Senior Design, Fall 2026

TA: Jianchong Chen

18 September 2026

Project No. 49

1.1 Problem

People with blindness or severe vision problems often receive their spatial information through a cane, a guide dog, audio, braille, or another person. These methods are valuable, but each has limits. A cane can only work with objects close to the user, fixed textile maps only exist in the few places they have been installed, and audio interfaces might interfere with environmental sounds that may be important for safety. Conventional refreshable braille displaces efficiently communicate words, but they do not provide a two-dimensional tactile representation of nearby scenes. This need is therefore not simply object recognition but a compact way to let a user independently inspect the shapes and location of obstacles and feel the scenes and boundaries before reaching them.

The scale of the concern is substantial. The World Health Organization reports that at least 2.2 billion people have near or distant vision impairments worldwide and estimates annual global productivity losses associated with vision impairment is approximately 411 billion dollars[1]. Vision loss can reduce mobility, educational access, workforce participation, and independence. These effects are distributed unevenly as access to eye care and assistive devices is lower in many low income settings[1]. A tactile scene display cannot replace medical care, such as mobility training, a cane, or a guide dog, but it could add another channel for understanding nearby space.

The design also addresses cultural and ethical concerns about assistive products that make decisions for users. A system that announces labels for nearby objects may have uncertainty and can create confusion when the classification is wrong. Our proposed device instead performs a deterministic grayscale and edge processing and presents a simplified tactile image that will leave no confusion. This leaves interpreting the geometry to the user giving them

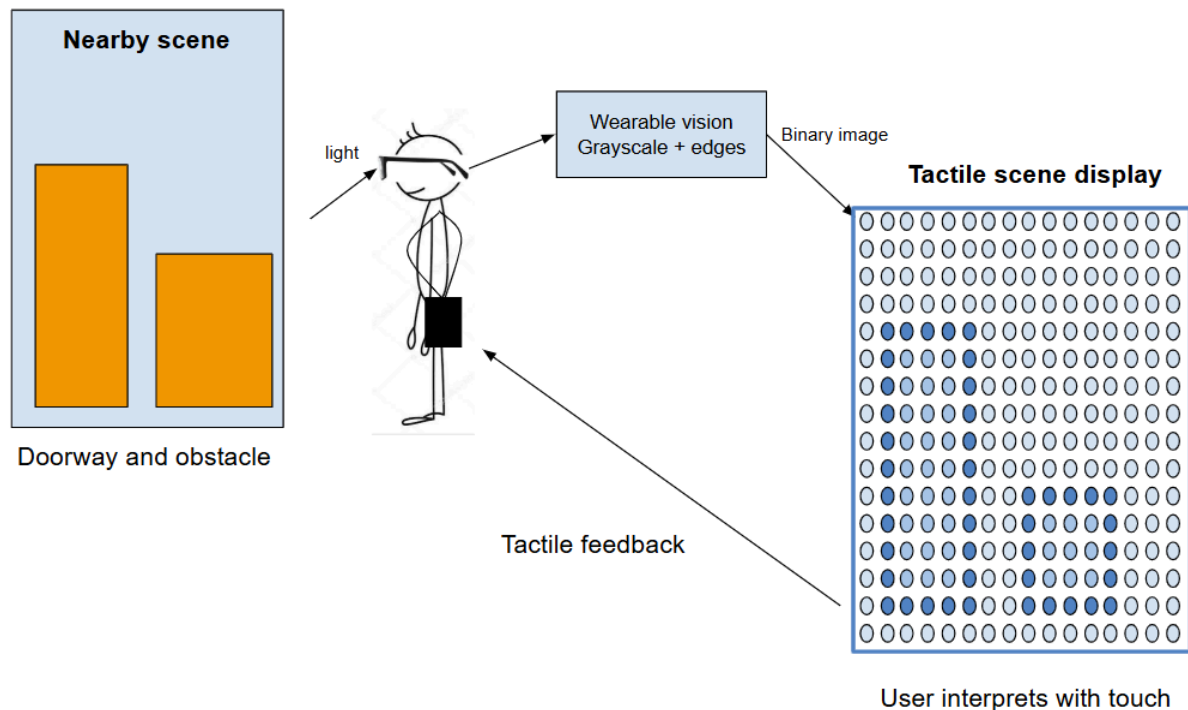
more confidence in their decision making. Not only does this allow users to have the capacity to act independently, it also reduces computation, network dependence, and data collection associated with cloud-based recognition. It could also lower the economic burden relative to a design that requires continuous third party interference.

1.2 Solution

We propose a wearable camera connected to a local embedded vision processor and a handheld 32x32 tactile pin display. The camera observes the scene in front of the user. The processor converts each frame to grayscale, suppresses noise, extracts strong intensity boundaries, and reduces the result to a 1024-pixel binary map. It then transmits the maps over a 3.3V UART link to an ESP32 display controller. No image will leave the device or be stored internally providing more security to the user.

The display controller validates each frame, configures the device to the correct starting position, and moves a row of 32 reversible electromagnetic actuators across 32 rows. At each row the controller pulses the appropriate coils in the two banks of 32 to raise or lower mechanically bistable pins. Because each pin retains its state without continuous current, the user can explore a stable tactile picture while the coils are off. A hard enclosure, end stops, current limiters, a button to disable, and timeouts isolate the user from the moving carriage and prevent coil heating.

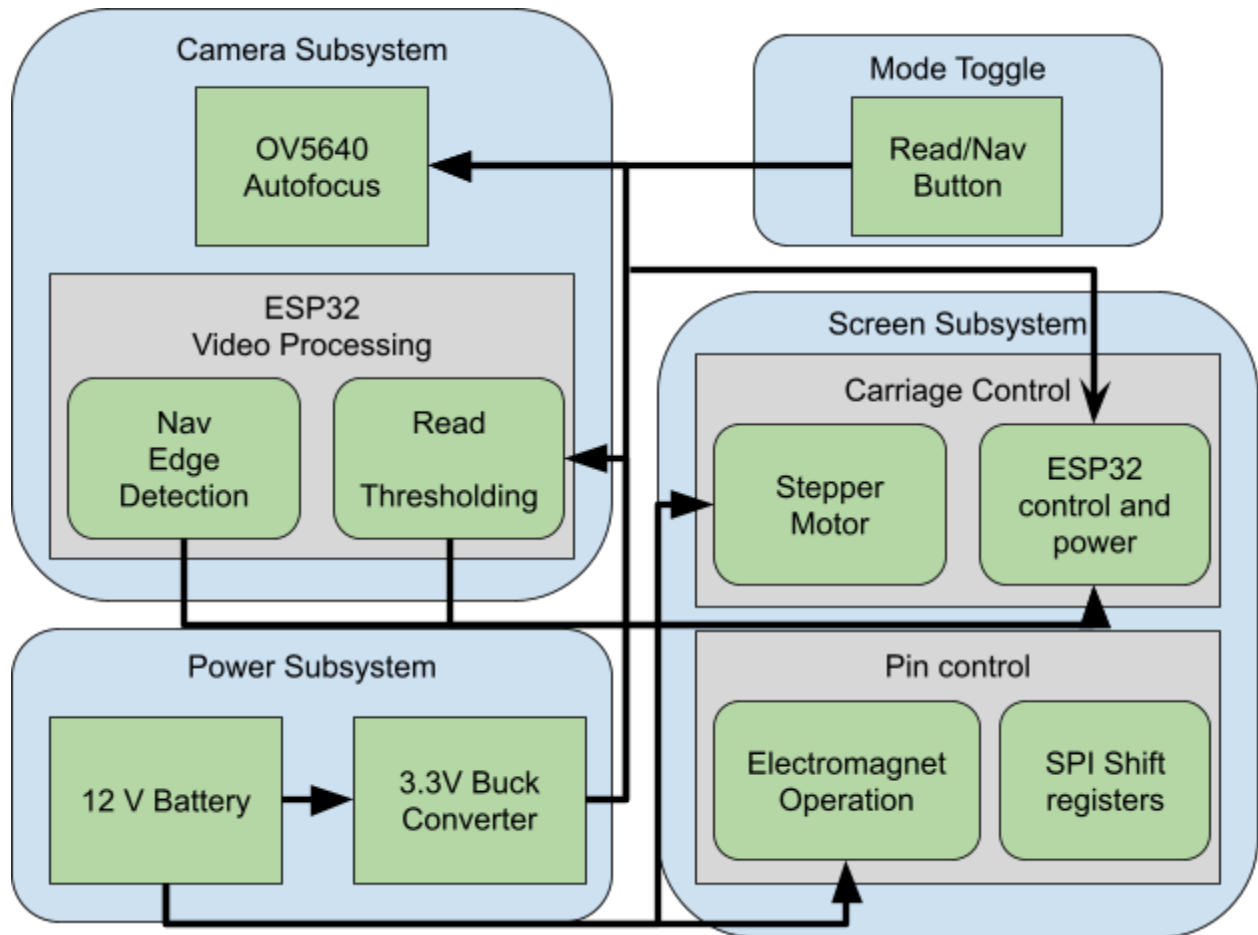
1.3 Visual Aid



1.4 High Level Requirements

- The system shall convert a captured scene into a complete 32 by 32 tactile frame with a refresh rate greater than 1 Hz
- The completed display shall match the commanded binary map for at least 972 of 1024 pins, corresponding to a 95% accuracy
- Every commanded raised pin shall extend 0.8 to 1.2mm above the nominal surface and shall resist a 0.15 N downward load for 60 second without returning to the lowered state

2.1 Block Diagram



2.2 Subsystem Overview

Camera Subsystem

The camera subsystem is used for capturing the user's surroundings and converting the captured image into a simplified binary image that can eventually be represented on the tactile display. It consists of a OV5640 autofocus camera and a ESP32 video processor, with the camera providing data to the ESP32. The autofocus on the camera allows for the user to operate it at different viewing distances.

The ESP32 processes the data depending if it is in read or navigation mode. In navigation mode, the image is brought to 160 x 160 pixels, in order to reduce computation. The image is later reduced to a 32 x 32 binary data, which represents what will be presented on the tactile display. When the ESP32 is in reading mode, it uses contrast in order to read the text on the display. Once everything is processed, it is sent to the tactile display controller, which controls the tactile screen display.

Mode Toggle Subsystem

The mode toggle subsystem allows the user to choose to be in the reading or navigation mode. This will be implemented using a physical button the user can press, which will send data to the ESP32, telling it which mode to be in.

Power Subsystem

The power subsystem will be the source of the main electrical power. A 12V battery serves as the main power. Control electronics that operate at lower voltage, will be controlled at 3.3V by using a buck converter that takes 12V and reduces it to 3.3V. This subsystem supplies the camera, processing units, and the screen subsystem. Regulated power is important to make sure that each subsystem receives the required amount of power to operate properly.

Screen Subsystem

The screen subsystem converts the image received from the camera subsystem into a physical tactile image. There is a carriage control and pin control. The carriage control contains an ESP32 and stepper motor. The ESP32 receives the processed image data, and determines what pins need to change state and controls the movement of the carriage across the display. The motor positions the carriage so that the appropriate row of pins can be updated.

The pin control raises and lowers the individual tactile pins. SPI-controlled electronics receive commands from the screen ESP32 and select which magnets need to be changed.

Electromagnets generate a magnetic field that moves the magnets attached to the pins.

Because the pins are bistable, they remain in their current position even when the electromagnets are turned off; therefore, does not require continuous power.

2.3 Subsystem Requirements

The camera subsystem must capture image information with enough resolution and focus in order for the image to be properly deciphered by the ESP32 and create accurate tactile representations. As previously mentioned, the OV5640 autofocus camera will provide the data to the ESP32. In navigation mode, the camera should be able to pick up accurate data in the 1 - 2 m from the user, while on the other hand, in reading mode the camera should support focusing at 30 - 40 cm.

The ESP32 has 2 ways to process image information. The ESP32 can reduce the input image to 160 x 160 pixels. Using Sobel edge detection, the image will then be reduced to 32 x 32 binary for the tactile display. The purpose of this is to reduce noise while keeping the important information.

In reading mode, the processor can operate on a 64 x 32 pixel region near the image captured. This mode will use Otsu thresholding, in order to help distinguish the text from the background. Once processed, it will be shrunk to a smaller 32 x 16 pixels for the tactile display.

The camera subsystem should be fast enough in order to have a greater than 1 Hz tactile refresh rate. The frame data will be sent from the vision processing ESP32 to the screen ESP32 through a 3.3V UART connection.

The power subsystem will provide enough power so that all components operate properly. It will contain a 12V source, with a buck converter that can change the battery voltage to 3.3V for ESP32 and other low voltage devices. The subsystem must remain stable during operation so that components do not fail or cause a reset.

The screen subsystem must convert the image to a 32 x 32 tactile display containing 1024 pins. There must be a 95% accuracy when operating the pins. The raised pins need to extend on average about 1mm and must be able to support a downward force of 0.15 N for at least 60 seconds. The screen must update at 1 Hz.

2.4 Tolerance Analysis

It is important to check whether the permanent magnets attached to our pins have enough holding force to keep the pin in the raised state while the user is touching the display. Our current design uses about 1.5mm diameter by 1mm thick neodymium magnets that latch against a thin steel layer. After the initial electrical power, the magnet must be held in place with any electrical power. With our current specifications, our design requires the pin to be held up for 60 seconds with a constant force of 0.15 N for at least 60 seconds. In order to find area of the magnetic: $A = \pi\left(\frac{1.5 \times 10^{-2}}{2}\right)^2 = 1.77 \times 10^{-6} m^2$. Using the magnetic pressure equation:

$$B = \sqrt{\frac{2\mu F}{A}} = \sqrt{\frac{2(4\pi \times 10^{-7})(0.15)}{1.77 \times 10^{-6}}} = 0.462 T.$$

Therefore, about 0.462 T at the magnet and steel interface would be required to create the 0.15 N holding force. As a comparison, a N52 neodymium magnet with dimensions around ours, has a pull force of 0.31 N, against a steel source. This is about 2.1 times our project's holding force, and indicates that our proposed size and holding force is plausible.

However, it is important to note that this is the ideal case. The holding force of the N52 neodymium magnet could be impacted for a multitude of reasons. This could be caused by a thin steel layer, if there is a problem with complete contact on the surfaces, or there is an air gap between the magnet and steel. On their website, manufacturers note that the thickness of the steel, how the coating is applied, and imperfect contacts can affect the pull force. This is

important for our design because the steel must be thin enough that the carriage electromagnets can still move the permanent magnets from one side to the other.

Therefore, the steel thickness and magnet to steel spacing will be treated as design tolerances for our project. Our group will target the measured holding force of at least 0.15 N, but will aim for a higher design target of 0.30 N, in order to provide a 2x safety margin. During prototyping, the group will test the steel thickness with a force gauge, with the thinnest steel layer that can provide the required holding force, while still allowing the carriage to switch the pin will be the selected steel.

3. Ethics, safety and societal impact

The IEEE Code of Ethics requires engineers to prioritize public safety and welfare, and disclose factors that may endanger the public or environment, improve understanding of technology and its consequences, protect privacy and make honest claims[2]. Those duties are especially important because the intended user may rely on the information our device supplies to move through an environment. We will describe the prototype as a supplemental scene tool, not a mobility safety device and not a substitute for a cane or dog. Accuracy results will be reported with the target patterns, lighting, distance trial count, and observed failures. We will not hide missed edges or present a single successful demonstration as general reliability.

A forward facing wearable camera can record bystanders, private spaces, or documents. The device will process these frames locally, store no raw video, provide a visible camera in use indicator, and include camera disable control and there will be no required network interface

The development hazards include high actuator current, hot coils and semiconductors, soldering, unexpected carriage motion, and pinch points. The 12V source is below hazard thresholds, but can still deliver enough current to heat wires or start a fire. We will make sure to use the correct current rated supply, include strain relief, use appropriate size conductors, reverse polarity protection, and covered terminals. During prototyping current limited bench supplies will be used and each H-bridge channel will be tested with one actuator before added to the array.

The intended benefit is greater independent access to spatial information without the user being forced to rely on possible misinformation from AI generated object labels. The system should support, rather than assign how a person navigates. However, an incorrect tactile map, or a bulky slow device can create false confidence, these risks make designing require honest limitations statements.

A lower cost electromechanical array could make two dimensional tactile graphics more available in classrooms, workplaces, and low-resource settings, but the prototype should not be targeted for an affordability claim. The 1024 precision pins, 32 actuators, mechanical guide, and assembly time may create a cost.

Environmental impacts include copper and steel in coils, permanent magnets, PCB's, plastic enclosure material, and electronic waste. The prototype will be designed in a modular way allowing for repair and replacement. Components and wiring will be labeled.