Advanced Navigation System for People with Low Vision

MICHIGAN ENGINEERING
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naviband

BACKGROUND

- Prevalence of low vision patients is projected to impact nearly 10% of the general population by 2050
- Aging populations are specifically very susceptible and many patients adapt to the situation in maladaptive ways

EXISTING SOLUTION

- The white cane - effective but slow at telling the user about their environment
- Only provides a single point of information at a time.

OUR SOLUTION

- Our solution employs:
  - **DEPTH CAMERA** with a robotics path generation algorithm
  - **HAPTIC WRISTBAND** with embedded motors
- Provides more environmental information than a cane

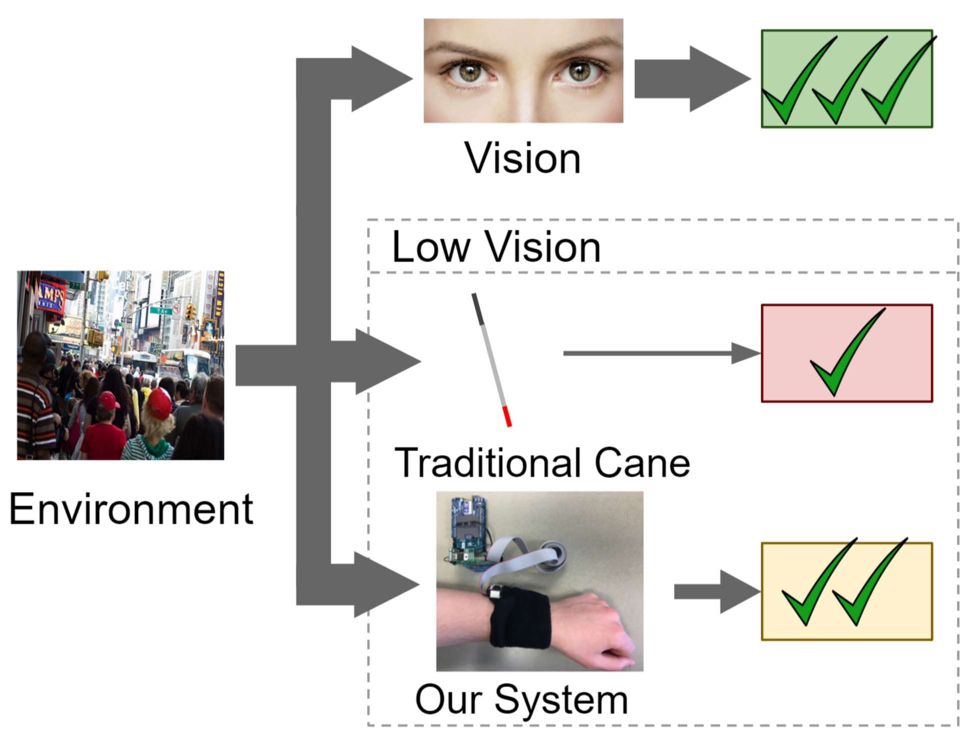
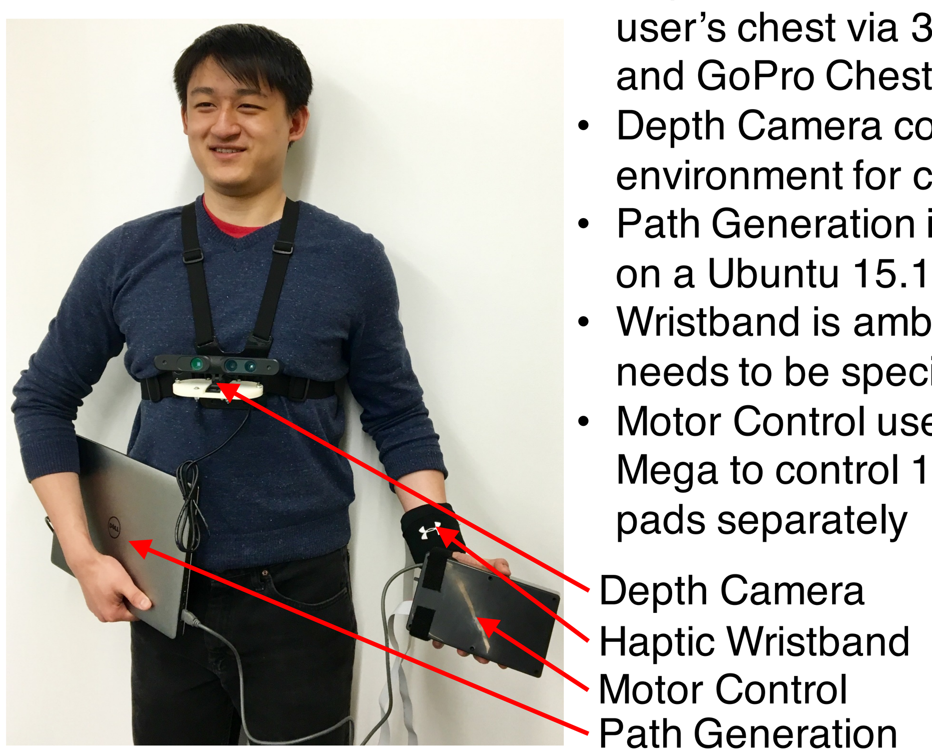


Figure 1: System Comparison



- Depth Camera is strapped onto user's chest via 3D printed mount and GoPro Chest strap
- Depth Camera constantly surveys environment for clear paths
- Path Generation is run on laptop on a Ubuntu 15.10 virtual machine
- Wristband is ambidextrous but needs to be specifically oriented
- Motor Control uses an Arduino Mega to control 14 vibrating motor pads separately

Figure 2: Separated Prototype Components

- Hands-free usage if Motor Control and Path Generation systems are stored in backpack
- Allows for paired usage with White Cane and/or guide dog
- Wristband instructs user where to go or to stop
- Wristband provides intuitive feedback that is independent of arm position whilst walking

Figure 3: Hands-Free Prototype Usage

VISION AND PATH GENERATION

Specifications

- Hardware: ASUS Xtion Pro Live Depth Camera
- OS: Ubuntu 15.10
- APIs used: OpenCV (Computer Vision), OpenNI (Natural Interface)
- OpenCV API is used for image and matrix processing
- OpenNI provides camera API and interfaces directly with the OpenCV API

Overview

- Camera is mounted securely on chest for stability
- Path Generation algorithm was adapted from a specific occupancy grid algorithm: "Vector Field Histogram"
- Vector Field Histogram provides analysis on a top view of a user's environment
- 5 Data transformations/reductions are performed from the original depth image as detailed below
- Two Overall Objectives:
  1. Generate Top View from Depth Image *(Steps 1 & 2)*
  2. Vector Field Histogram Data Reduction *(Steps 3 & 4 & 5)*

Path Generation Algorithm

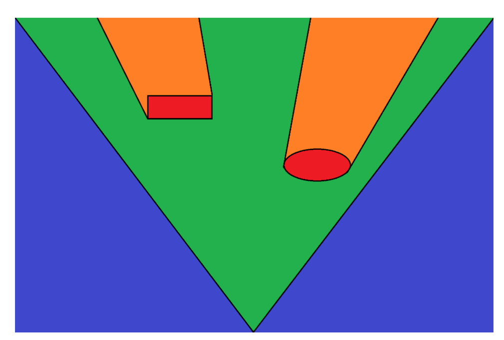
Generate Top View

Step 1: Depth Data Capture

- ASUS Xtion Pro Camera provides depth image (mm)

Step 2: Top View Generation

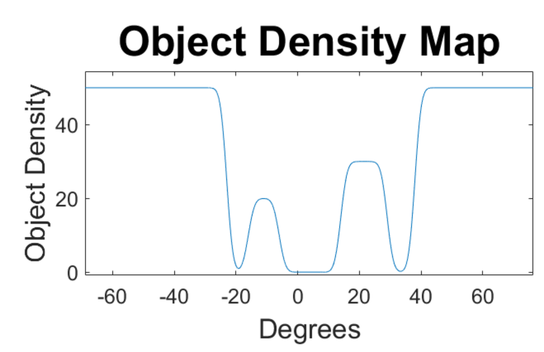
- 2D environment viewed from top is generated from depth Information
- Known Obstacles (Red) are mapped as from the Depth Image
- Unknown information (Blue and Orange) is mapped as a blocked path
- Remaining (Green) are clear paths
- If Obstacle or Unknown → "1"
- If Clear Path → "0"



Vector Field Histogram

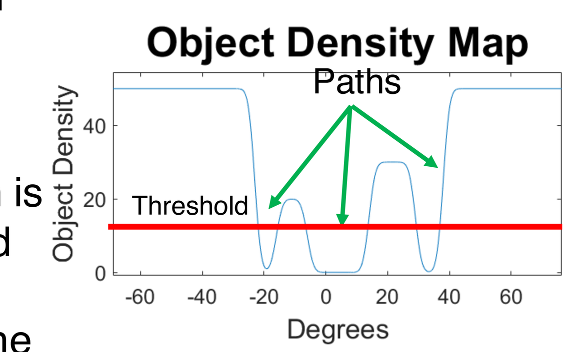
Step 3: Object Density Plot

- Top View is converted into a Polar image with camera position as the center of transformation
- Rows (in polar representation) are summed



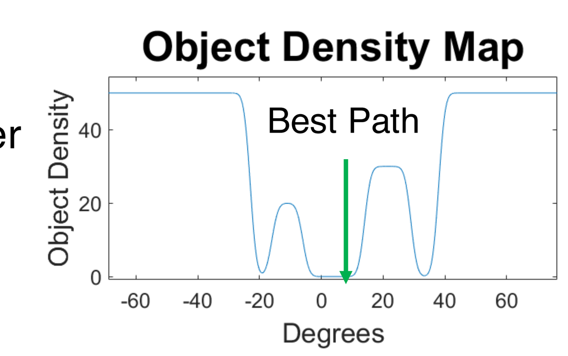
Step 4: Path(s) Detection

- Local Minima are considered open paths
- Local Maxima are considered obstacles
- What is considered an "open" path is thresholded at a object density and width
- All potential paths are found and the angle to the path(s) center



Step 5: Singular Path Selection

- A singular path to convey to the user via the haptic wristband is selected
- Selection for the closest path is selected



HAPTIC WRISTBAND

Wristband Design and Construction

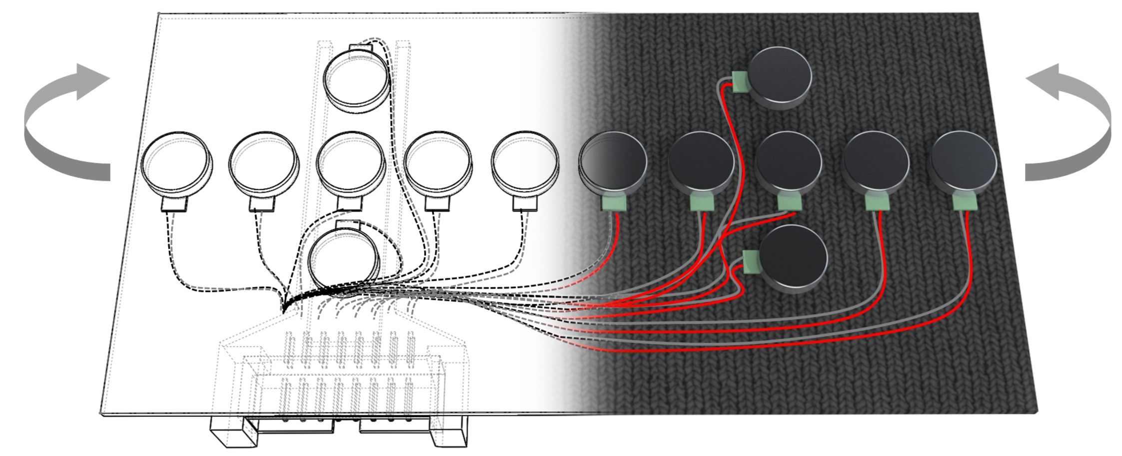


Figure 4: Unwrapped schematic of the haptic wristband.

- Assembly
  1. Vibration pads, connector port, and wires are epoxied (with strain relief) to a thin elastic wristband.
  2. wristband is rolled into a cylinder with the vibration pads on the inside.
  3. Finally, this assembly is inserted into another elastic wristband to insulate wires and vibration pads from direct contact with the skin.
- Each vibration pad is independently drivable
- Allows for arbitrary sequence of pads to be used as gestures

Giving Directions to User via Gestures

- Left & Right: sequence of vibration around the wrist
- Stop: 5 successive pulses at all points around the wrist
- Forward: 3 pulses on inside of the wrist, decreasing in intensity

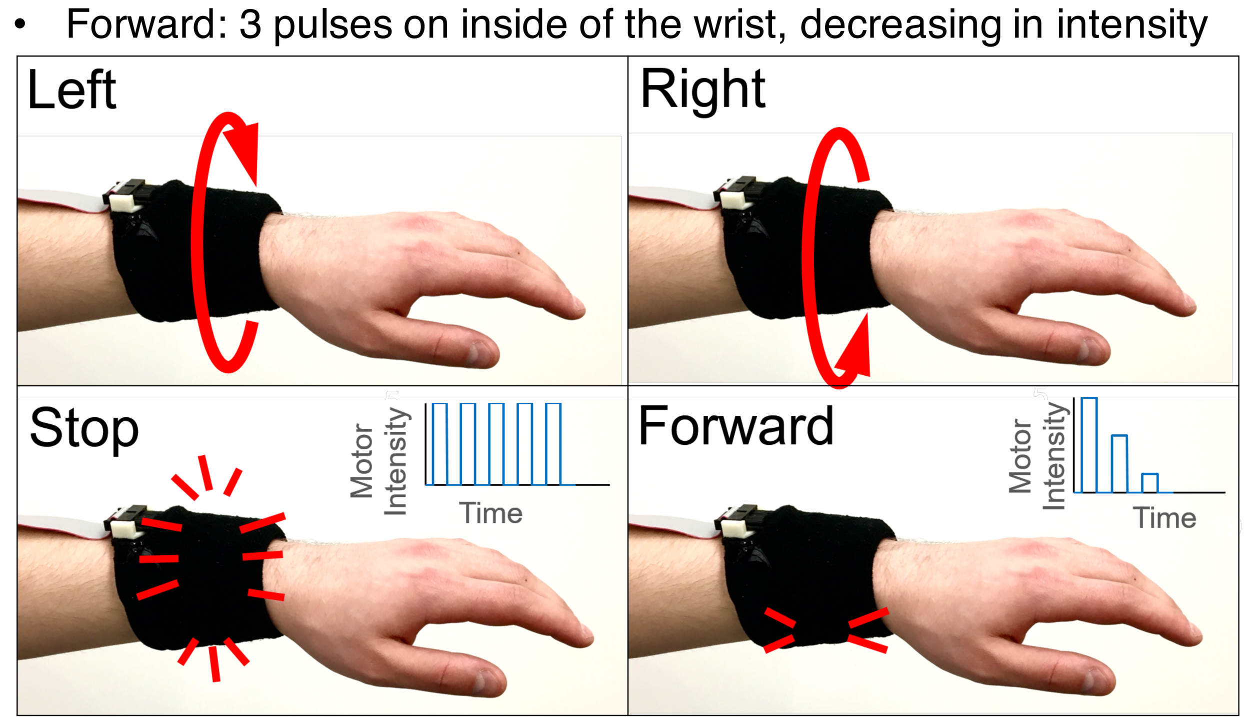


Figure 5: Current set of gestures implemented to direct user toward the path

Gesture Verification

- No clear trend exists for low-intensity (3.3V)
- For high-intensity, reaction time and variance decreases as speed increases.
- Absolute maximum rotations speeds were ~60-80 ms

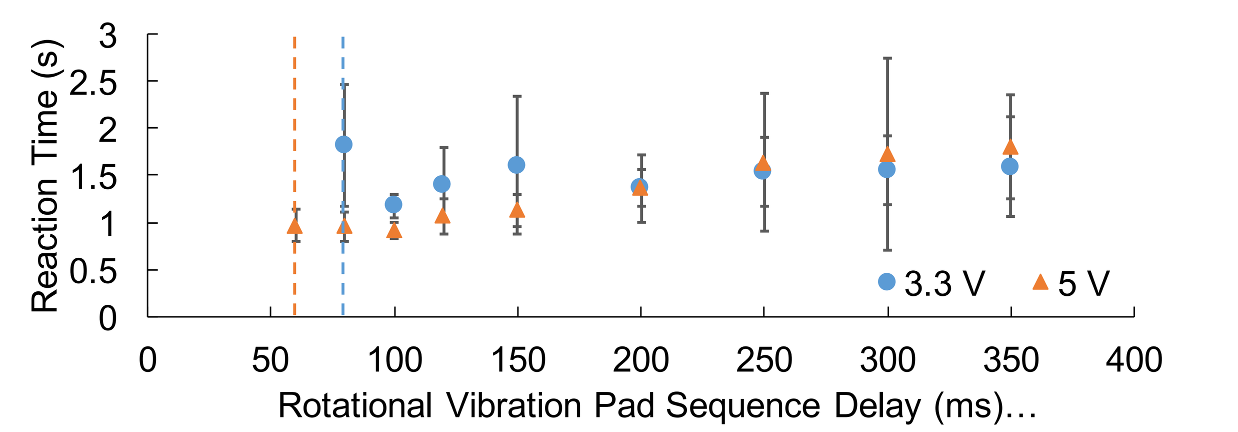


Figure 6: The effect of rotation speed (inverse of vibration pad delay) and vibration intensity (controlled by voltage) on user reaction time

COMMUNICATION

- Angle is converted into direction code
- Direction code sent over serial port to arduino
- Arduino code provides gesture based on direction code

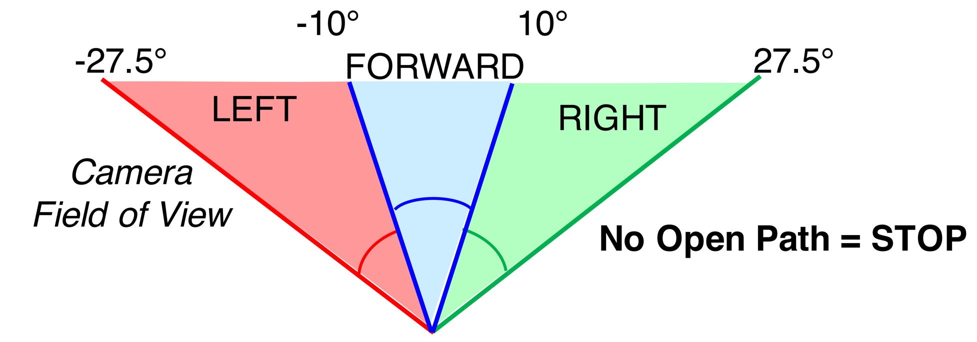


Figure 7: Direction code converts the angle provided by the path generation to a direction which is then relayed to the Haptic Wristband. Angles are not to scale

FULLY-INTEGRATED SYSTEM TESTING

- Tested in real life environments
- Further validation can be done by creating an artificial path in an open area
- Solution is robust but has hardware limitations and noticeable processing time lag

Validation Test Setup

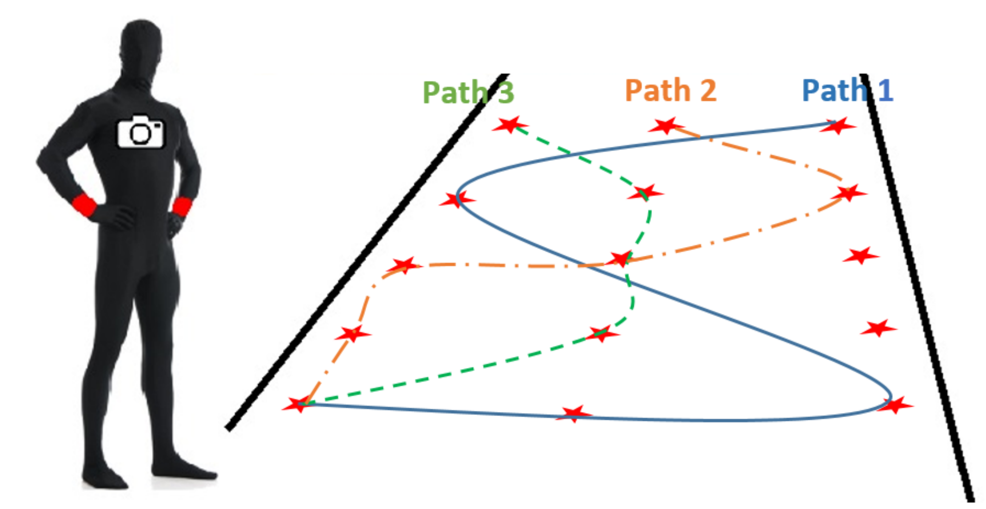
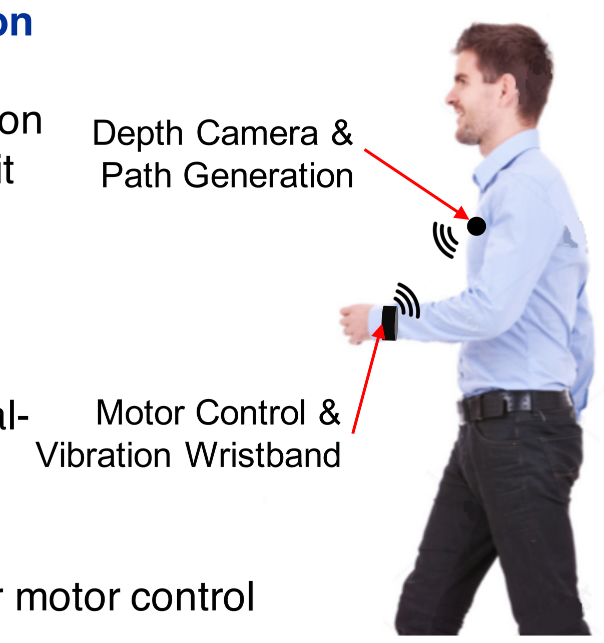


Figure 8: Virtual path creation examples for validation testing. Each star represents the location of a potential obstacle.

IDEAL SOLUTION IN 5 YEARS TIME

Vision and Path Generation

- Specialized, integrated electronics for computation
- Inertial measurement unit to allow for environment memory.
- Cheaper, smaller, more-stable camera
- Faster processing for real-time feedback



Haptic Wristband

- Integrated electronics for motor control
- Integrated battery
- Wireless communication with vision system
- More vibration pad density (higher resolution)
- More intuitive haptic feedback (electrodes)

ACKNOWLEDGMENTS

- Dr. Donna Wicker (Kellogg Eye Center)
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