OVERVIEW
The BBA (Blind Bowling Assistive) device was created for the purpose of increasing the independence of visually impaired bowlers. It does this by providing information on the locations of remaining pins and the location where the ball made contact with the pins after each throw. This information is gathered using image processing software and then relayed to the user via a tactile display.

SPECIFICATIONS

<table>
<thead>
<tr>
<th>Metric</th>
<th>Target Value</th>
<th>Value Achieved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Device Size</td>
<td>4x6x6 in.</td>
<td>3.75x6x6 in.</td>
</tr>
<tr>
<td>Device Accuracy</td>
<td>99.9%</td>
<td>98.2%</td>
</tr>
<tr>
<td>User Interpretation Accuracy</td>
<td>99.9%</td>
<td>97.9%</td>
</tr>
<tr>
<td>Battery Life</td>
<td>3 hrs.</td>
<td>10 hrs.</td>
</tr>
<tr>
<td>Setup Time</td>
<td>5 min.</td>
<td>10 min</td>
</tr>
<tr>
<td>Cost</td>
<td>$300</td>
<td>$250</td>
</tr>
<tr>
<td>Motor Actuation Speed</td>
<td>5 sec.</td>
<td>3 sec.</td>
</tr>
<tr>
<td>Image Processing Speed</td>
<td>40 ms.</td>
<td>31 ms.</td>
</tr>
</tbody>
</table>

TACTILE DISPLAY
The tactile display consists of 10 pins actuated by servo motors and a slider actuated by a motorized potentiometer. All motors are controlled by a Romeo microcontroller.

PIN ACTUATION
Servo Configuration

- Size: 22 x 12 x 30 mm
- Voltage: 5 - 7.2 V
- Current Draw: 3 mA (no load)
- Stall torque: 4 lb-ft

Small servo motors are necessary to minimize the size and cost of the device. Additionally the servo motors have a high stall torque so that they can not be easily back driven by a user feeling the display. Servo motors are connected to the display pins in a cam follower configuration and rotate an average of 20 degrees in order to achieve desired pin movement.

SLIDER ACTUATION

Motorized Slide Potentiometer Specs:
- Size: 112 x 13 x 43.2 mm
- Voltage: 5 - 10 V
- Linear traveling speed: 20 mm / sec.

This motor was chosen for its small size and ability to actuate linearly. It has a DC motor that is attached to a belt that moves the silver slider back and forth. It was also chosen because it has a linear potentiometer built in, which allows the device to accurately move the slider to the correct position.

IMAGE PROCESSING
A camera is set up at the end of the bowling lane near the pins. The video feed is relayed to a laptop computer which processes the image using C++.

PIN LOCATIONS

In the first ten frames after startup the program locates pins and stores their positions. See Figure 1. When a change is detected the program waits a set number of frames then captures the pin states and sends them to the microcontroller. A change is detected when the ball strikes a pin or, in the case of a gutterball, when the pinsetter drops in front of the pins, see Figures 2 and 3 (red dot indicates change)

BALL LOCATION

The ball is primarily located by detecting changes in the pin states, but this method cannot be used for detecting gutterballs. Gutterballs are instead tracked by movement and location on the screen, see Figures 4 and 5.

CONCLUSION
A successful device was created that accurately relates remaining pin locations and location of ball contact. This device meets all of the set specifications determined by customer surveys and user testing. The BBA device consists of the tactile display, a wireless webcam viewing the pins, and a laptop. The laptop is used to receive the images from the camera, run the image processing software, and control the tactile display.

Additional testing with more visually impaired individuals would be beneficial for the future development of this device. Other suggestions for future improvements to the device would be to eliminate the need of the laptop and install all software onto the tactile display console, as well as, using the bowling alley lane camera to view pin positions.

Blind Bowling Assistive Device
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