A Low-Cost Collision Detection System for Compact Vehicles
(aka “Ping Around the Rosey”)

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The Goal...

• Create a low-cost, ultrasonic proximity detection system to act as first line of defense in autonomous driving/parking system.

• Couple visualization sensitivity of sonar data with driving speed.

• Evaluate the efficacy of sonar for autonomous driving applications.
Commercial Applications

Low-Speed Collision Detection for Parking Assist

- Range: 10 cm - 1.5m
- Designed for low-speeds
- Highly-directional and subject to interference
Sonar Methodology

- Sensor outputs sonar pulse at 40 kHz and measures corresponding echo in receiver.
- Range: 2cm - 3m
- TTL pulse width corresponds to time it takes for echo to strike target and return to sensor

- Construct an array of eight sensors placed circumferentially around the vehicle body
- Sequentially fired (1, 2, 3, 4, 5, 6, 7, 8)
- Maximum TTL pulse = 18.5 ms so: 
  
  \[(8 \text{ sensors} \times 18.5 \text{ ms}) = 148 \text{ ms}\]
- Firing delay of 25 - 50 ms used to limit data flow to Serial port
- Can measure full array of sensors in 200 ms max, so can get five full measurements/second
Tachometer Methodology

- Hall Effect Sensor: ATS177
- Hall plate detects changes in magnetic flux density (B-field)
- Output goes low when B is larger than operating point
- Held low until a magnetic flux density reversal occurs

- Comparator amplifies Hall voltage
- Schmitt Trigger provides switching hysteresis and high/low output
- Output transistor pulls output low when Schmitt Trigger outputs high

- Attached permanent magnets to disc on DC motor (two for balance)
- Sensor detects when a magnet passes by and outputs low
- Trigger a spin “count” event on falling edge with an interrupt signal to microcontroller
Signal Processing

• Sensor array fired sequentially in rounds of ~200 ms
• TTL sonar pulse widths converted into distances using known speed of sound
  \((c_{\text{sound}} = 343 \text{ m/s at room temp, sea-level})\)
• Distance measurements stored in array and printed to Serial port

• Hall effect sensor going low triggers ‘FALLING’ interrupt on microcontroller
• Triggers increment of a rotation
• RPM is calculated using the number of counts in a fixed time interval measured with the system clock
• RPM value is appended to the Serial port output

\(\Delta t_{\text{fall, min}} = 15 \text{ us}\)
Visualization

- Processing sketch picks up array of sonar values and RPM from the Serial port
- Ellipses change size, color, and transparency based on proximity data
- $\log_{10}$ scaling used to improve smoothness of visualization
- Threshold ranges for each color scheme and for minimum distance of alarm
- RPM value translated into multiplier based on speed of the vehicle to augment apparent danger
- Color data & visualization can be directly ported to ambient lighting for car
Challenges

- Separation of motor power & signal power
- Isolation of Arduino analog & digital grounds
- Sensors need a robust 5V
- Vibrations of motor on polycarbonate plate may interfere with 40 kHz sonar pulse
- Foam padding required to prevent reflections off base-board
- Saturation of sonar readings can delay sensors ability to pulse rapidly
- High RPMs from tachometer measurement are hindered by minimum rise/fall time of hall effect sensor output (1.5 us) and perhaps even further by read rate of ATMega328 & Serial port
- Max measurable RPM: ~ 9000
Conclusions

- Sonar is noisy!!
- Narrow cone of sonar sensor requires many sensors for full coverage
- Certain materials absorb sonar pulse
- Multiple layers of sensing/detection will be required for fully autonomous operation
- Serial output gives variety of possibilities for visualizing output but has limited bandwidth with ATMega328
- Sequential firing is faster than spinning sensor and reduces potential for crosstalk because only one sensor is active at a given moment
References

Hardware & Software Design
- Arduino Website (www.arduino.cc) & open-source code library
- Parallax Website (www.parallax.com) & sensor data sheets
- Processing Website (www.processing.org) & open-source code library
- ATS177 sensor data sheet (www.diodes.com)
- ATmega328 data sheet (www.atmel.com)
- StackExchange (http://electronics.stackexchange.com/)
- MAS.836 Lecture Notes (http://media.mit.edu/resenv/)

Commercial Application ("Park Assist") Images
- Gizmodo (www.gizmodo.com)
- Can I Do It? (www.canidoit.org)