Preventative Algorithms to Capture the Early Onset of Carbon Monoxide Release

David Blincoe
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ABSTRACT

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Carbon monoxide poisoning is a problem that causes 15,000 injuries and 430 deaths per year in the U.S. As keyless ignition systems in automobiles have become wide spread, so have the substantial safety risks associated with these systems. Carbon monoxide related deaths and injuries have been reported when cars were accidentally left running or failed to shut down when the driver left the vehicle. This research is aimed at developing an algorithm that has the ability to predict rather than react to high concentrations of carbon monoxide. This sensor is programmed to have the ability to act upon this early detection by sending a signal that will open a garage door and eliminate the buildup of carbon monoxide. Four sources that produced carbon monoxide were used to test the algorithm against a commercially available sensor. The experimental sensor was shown to predict and activate at a significantly earlier time exposure than the commercial sensor. The experimental sensor and its implementations shows promising potential as a device that could save lives.

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INTRODUCTION

Carbon monoxide (CO) is a colorless, odorless lethal gas that can easily go undetected. This small molecule binds easily with red blood cells essentially blocking oxygen binding and causing eventual death. Even with certified CO detectors there is no guarantee that gas leaks will be detected, as low levels can remain constant at the site of the detector but can accumulate elsewhere in higher levels. In a study done in 2011, residential CO detectors were found to be faulty in over 50% of the models tested (Ryan & Arnold, 2011). These CO detectors work using a time weighted average (TWA), which is the average exposure within a confined area to any contaminants (Lees & Breysse, 2016). The CO must be detected at a prescribed level within a specific time interval before being activated. This level is set at 50 ppm TWA (US Dept. of Labor). This research is designed to create algorithms that are able to predict dangerous levels of CO rather than allowing the high levels to accumulate before being detected as standard CO detectors do. The program is designed to store the past readings in a SQL database. The program is able to asynchronously fetch the data. The data can then be pushed through a slope function to determine the average rate of change. This can impart information of the overall trend of CO levels. Based on the average rate of change, the algorithm is able to calculate a trigger level. If the program senses that the rate will exceed the trigger level in a calculated amount of time, the alarm will activate. Rate of change detection is preferable to TWA because it allows for prediction of high CO levels rather than the waiting for actual CO levels to reach a dangerous level. There can then be a push notification sent to an accompanying app that will alert the user. The framework that the notification is built upon can also allow for specific uses to open a garage door automatically or to shut off a gas furnace in the face of danger. In addition, standard CO detectors can become uncalibrated over time leading to inaccuracies. This research is designed to allow the detector to recalibrate itself on a regular basis. This calibration will function by testing the average value of the data over a pre-specified time interval. The sensor can remain accurate by recalibrating itself to clean air.

This computer-based research is being developed to be implemented in various situations. The area of focus for this project is the CO accumulation in garages. This has become an increasingly widespread problem when keyless vehicles are left running inadvertently. This keyless feature allows the driver to exit the vehicle with the key fob while the vehicle continues to run and emit potentially lethal levels of CO.

MATERIALS AND METHODS

A. Acquisition of Materials

The following items were purchased online: MQ7 gas sensor, single channel relay, SMART ultrasonic sensor, and 3 prong connector. The following items were procured from CanDo: Beaglebone Black arm chip Rev. C, male to male jumper cables, potentiometer, casing, and LEDs. The garage door opener was from my home. The Kidde carbon monoxide detector was purchased from Home Depot. The four sources of carbon monoxide included: the Bunsen burner, the oil lamp, the charcoal, and the two-stroke engine. The oil lamp, charcoal, and two-stroke engine were acquired from my home, while the Bunsen burner was from Villa Madonna Academy.

B. Preparing for Data Collection

A program was written in Java to read the analog values from the MQ7 gas sensor. The program is a multiclass structure that implements Beaglebone Blacks GPIO and ADC ports. The analog output from the gas sensor is scaled down by a factor of 2.77 through the use of a potentiometer. This is required because Beaglebone's ADC ports can handle a maximum of 1.8v versus the 5v max that the gas sensor gives out. The program samples this value at a given time interval. The voltage sample is converted back to 5v and given an ID and a timestamp. The voltage object is then inserted into a MySQL database where it is stored until it is either read by the algorithm or is called by the client side charting webpage.

In deciding how to proceed with the data collection, safety concerns did not allow for a full-scale test. The determination was made to use a fume hood to test the sensors.

C. Data Collection

Data was collected under a fume hood at Villa Madonna Academy. Four potential CO producers were tested. These included the standard Bunsen burner, the oil lamp, the charcoal, and the two-stroke engine. Each of the four producers were placed under the hood along with the experimental sensor, the commercial sensor, and a laptop for data collection and timing. The hood was sealed after igniting each source and starting the timer and data collection. Each source was run until the average rate of change equaled zero. In between each run, the experimental sensor and the commercial sensor were reset and the airspace under the hood was replaced five times to ensure that there was no residual gas left under the hood. Each of the four producers were run in sequential order two times. The commercial sensor readings were in ppm, while the experimental sensor readings were in volts.

D. Data Analysis:

The concentration of CO varied greatly depending on the source. The oil lamp and the Bunsen burner produced the least amount of CO, producing negligible CO levels after burning for 5:32 and 5:55 respectively. There was no discernable detection from either of the sensors under the hood. The third source tested was the charcoal, placed in an elevated metal housing to allow oxygen to flow freely around it. The burning charcoal produced 35 ppm in Run A and 240 ppm in Run B, as measured by the commercial sensor, after burning for 30:00. The final source, the two stroke engine, showed the highest levels of CO with readings of 783 ppm in Run A and 553ppm in Run B after running for 10:00.

	Run A	Run B
Bunsen Burner	< 30	< 30
Oil Lamp	< 30	< 30
Charcoal	35	240
Engine	783	553

Table 1: Amount of CO Produced in PPM

Table 1, the data represents the CO production of instantaneous ppm for each of the four sources. The percent concentration was too low to be detected by the commercial sensor for the Bunsen burner and the oil lamp.

RESULTS

This research aimed to prove that the experimental sensor's response time was significantly faster than the commercial sensor. The algorithm was able to detect the rise of the CO while testing two of the four sources.

Charcoal: The charcoal, in both Runs, produced readable levels of CO, but the experimental sensor was only able to detect and activate in Run B as the levels in Run A were too low cause activation.

Figure 1: Voltage of Charcoal in Run B with the Experimental Sensor Detection Line

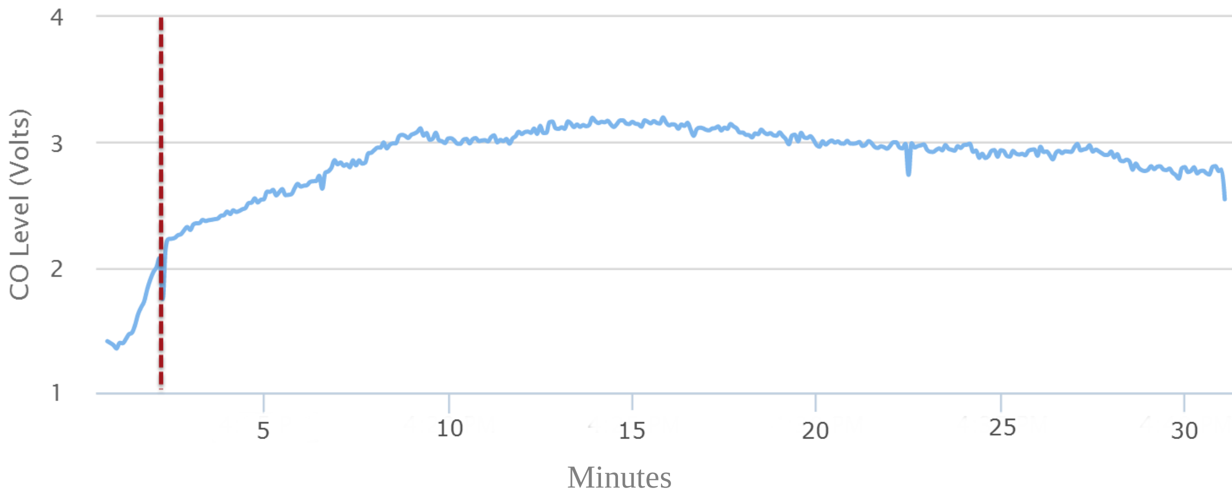

Figure 1 shows the voltage levels of the experimental sensor during the production of CO in Run B. The vertical red line demarcates when the experimental sensor was able to activate. The commercial sensor did not activate because the TWA would have taken more than an hour for activation to occur.

Engine: In the case of the engine, there was enough CO present to activate the alarms of both sensors. This allowed for the most accurate comparisons of the experimental sensor and the commercial sensor. The experimental sensor was able to use the algorithm to predict the rise of CO, therefore enabling it to activate at a much earlier period.

Figure 2: Comparison of Detection Times Based on Run A of the Engine

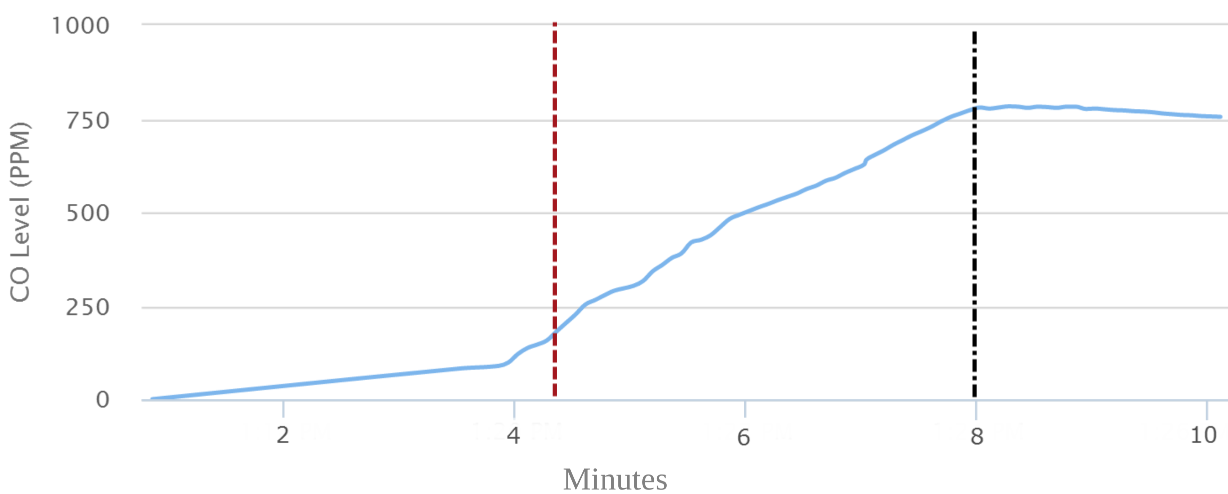

Figure 2 depicts the different lengths of time until the specific sensor activates. The vertical red line indicates the experimental sensor's activation and the vertical black line exhibits the commercial sensor's activation.

The experimental sensor was able to detect the carbon monoxide 3:30 before the commercial sensor. In Run B, the results were very similar with the experimental sensor detecting the CO 3:20 before the commercial sensor.

Figure 3: Comparison of Detection Times Based on Run B of the Engine

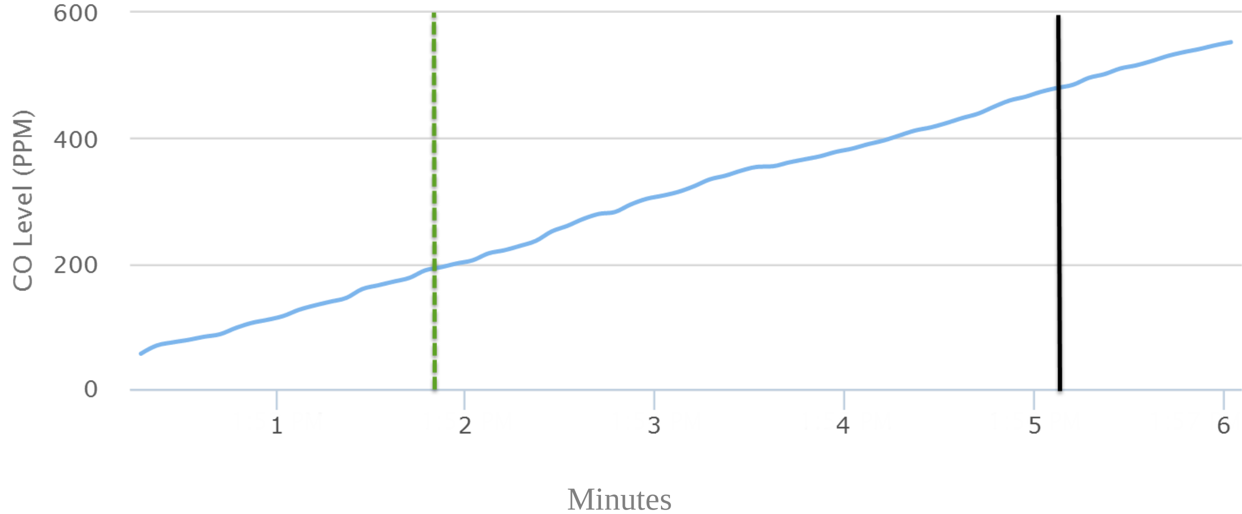

Figure 3, shows the interval between the experimental sensor's activation and the commercial sensor's activation. The vertical green line displays the experimental sensor's activation and the vertical black line demonstrates the commercial sensor's activation.

Figure 4: Comparison of Time Detection in Minutes

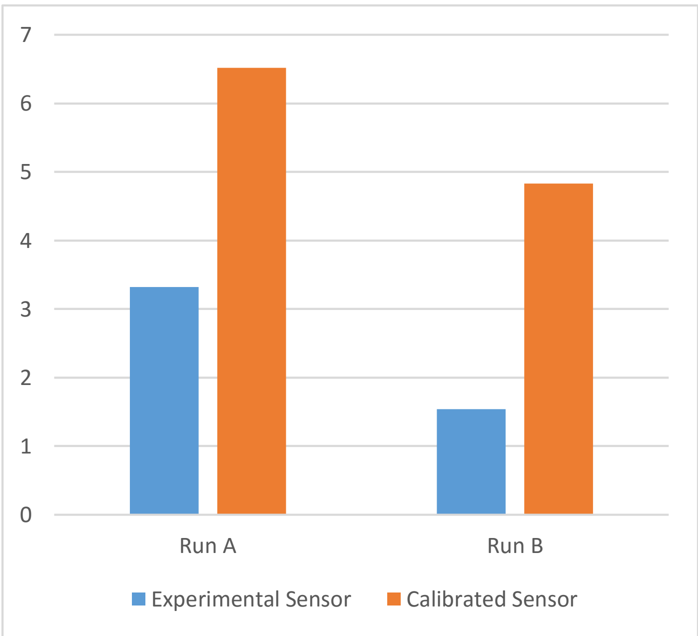

Figure 4, represents the difference in time between Run A and Run B for both the sensor's activation. The blue bar represents the experimental sensor and the orange bar indicates the commercial sensor.

DISCUSSION AND CONCLUSIONS

The goal of this research was to develop a carbon monoxide detector that used an algorithm to predict early onsets of high concentrations of this colorless, odorless gas. Carbon monoxide is responsible for 5149 accidental deaths from 1999-2010 (Xu, 2014). In addition, there are 15,000 injuries per year (Ryan & Arnold, 2011). The experimental sensor was able to detect early release of CO as shown in Figures 1, 2, and 3.

While the experiment was designed to test four sources of CO, only one source produced enough carbon monoxide for the commercial sensor to activate, therefore only allowing one source for direct comparison. Figure 4 shows clearly that the experimental sensor was able to detect CO at a much early onset. Where minutes matter, the ability for the sensor to predict CO at an earlier point could be lifesaving.

The initial idea for this research came from the problem of keyless and remotely started cars producing high concentrations of CO in closed garages. The algorithm has been designed around the ability to send a signal to the garage door if there are high levels of CO predicted and the sensor becomes activated. The signal causes the garage door to open, allowing CO to escape outside. This implementation of the sensor allows for it to be able to cut off power to various electrical devices that are prone to producing excessive CO.

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