Empowering Health and Environmental Awareness with Personalized Air Quality Monitoring

What’s the problem?
People are caring more about how the environment affects their health. Air quality is a primary concern as wildfires become increasingly prevalent year after year.

Our goal?
We aim to help individuals better understand their exposure to unhealthy air conditions by providing personalized air quality information.

Our solution.

Information about a user’s habits is collected from their Connect IQ account, demographic information is taken from the User Intake Survey.

Bluetooth Data Transfer
• BLE Component
  • Utilizes BLE for efficient and low-power wireless data transmission between the sensor device and the paired watch.
  • Users can monitor PM2.5, CO2, temperature and humidity conditions in real-time on their watch.

Watch
• Connect IQ Application
  • Collects heart rate and activity data to provide users with risk scores based on physiological data and real-time air quality information.
  • Integrates with Environment Canada Air Quality Health Index (AQHI) to feed into risk assessment algorithm.
  • Enriches activity fit files saved into Garmin Connect with air sensor metrics, graphs and personalized AQHI factors.
  • Interfaces with an API for seamless data integration into centralized database for further user metrics and visualization.

Algorithm
• Statistical Risk Modelling
  • Statistics extracted from over 30 studies evaluating different demographics, conditions, and their associated risks of air quality exposure.
  • Model sampled and posterior coefficients estimated to be used as risk parameters.

• Rate of Exposure
  • The exponential model was developed through an empirical study of populations (1).
  • The heart rate of a user is calculated by comparing ventilation to a standard (2).

• Location:
  • The user’s location is used to determine a coarse position for selecting appropriate reported AQHI and mapping of air quality.

• Personal AQHI
  • The rate of exposure ratio is used to augment the recorded air quality. The risk coefficients for a user are selected and combined for a risk factor.
  • The reported AQHI and feature-engineered bins have been selected. The calculated risk factor is compared to the bins to determine a personal AQHI.

Results
• Calibration
  • CO2: Linear regression model produced an R² of 0.976 and RMSE of 14ppm.
  • Corrected CO2 (ppm) = 0.655*Measured CO2 (ppm) – 300 (ppm)
• PM2.5: Multilinear regression model produced an R² of 0.626 and RMSE of 1.233 µg/m³.
  • Corrected PM2.5 (µg/m³) = 1.019*Measured PM2.5 (µg/m³) – 0.038*Measured Temp(°C) - 0.038*RH(%) + 2.8133(µg/m³)

Risk Statistic Results
Describe statistical analysis and risk modelling converged with Markov Chain Monte Carlo Sampling with a r-hat of 1.
• Risk statistics were utilized to develop a risk table for different air quality and heart rate.

Discussion
• Limitations
  • Due to the time constraints of the project, the PM2.5 sensor was only co-located for one week, providing a limited sample size for the feed-forward neural network.
  • The watch requires an active WiFi connection at the end of the activity to access the AQHI API, retrieve and send data from the database, and calculate a user’s personal risk score in the Connect IQ Application.

Next steps
• Perform a longer calibration for the PM2.5 sensor to fully capture a range of PM2.5 conditions and analyze the sensor’s drift over time.
• Recalibrate the sensor every six months per literature data to continuously validate the sensor data and further analyze the effects of temperature and relative humidity on sensor readings.
• Provide alerts and notifications of long-term exposure over multiple days/weeks.
• Seamlessly integrate user input form with the watch, potentially through QR code generation.
• Miniaturize sensor electronics and reduce the overall device footprint.

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Garmin Watch
Bayesian Model outputs a score defined as the “Personal AQHI” using a combination of demographic data, pre-existing conditions, and watch data.

User Front End

Personalized Air Quality Score

The “Personal AQHI” given to a user indicates degree of risk at the current time.
• User can decide how they want to interact with the environment based on this suggestion.
• User Front End in the Connect IQ Environment provides insights into data collected by the sensor and suggestions for behavior changes.

Abstract
• Combining a portable air quality sensor with health data collected by a Garmin wearable device.
• Delivering tailored insights and recommendations regarding air quality exposure to the user.
• Generating an overall, personalized, and actionable Air Quality Score.

Methods and Materials
Sensor
• Printed Circuit Board (PCB)
  • All hardware is integrated on a custom 4-layer PCB with dimensions of 8.6 x 5.9 cm.
• Sensing Systems
  • Sensron SP530 Particulate Matter Sensor measures the concentration of airborne particles 1 - 10 microns in diameter (between 0 - 1000 µg/m³).
  • Sensron SC40 Carbon Dioxide Sensor measures true CO2 concentrations in ambient air (between 400 - 2000 parts per million).
• Calibration
  • SDQ-40 is calibrated to a Vaisala CO2 reference monitor.
  • SP530 is calibrated to an API TE640 PM2.5 government reference instrument.
  • Analyzed and applied feed forward neural network/regression models to ensure accurate values.
• Auxiliary Components
  • Rechargeable battery system enables >10 days of continuous operation.
  • Two backlit buttons are integrated for user-friendly device control.
• Encasement
  • 3D printed encasement using 1.75 mm PLA filament.
  • Multiple layers of waterproofing.

BlueTooth Data Transfer
• BLE Component
  • Utilizes BLE for efficient and low-power wireless data transmission between the sensor device and the paired watch.

User Personal Health Information
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