Microcontroller-Based Atmospheric Sensing System

John Buglione[1], Andrew Ortiz[2], Lei Tao[3], Amir Khan[3], Kathryn Nicolich[4], Anthony O'Brien[3], Mark A. Zondlo[3]

Villanova University[1], University of Buffalo[2],Princeton University[3], Bucknell University[4]

Motivation

Global Warming is a problem widely recognized by the scientific community, but not fully understood. In order to further our understanding of greenhouse gases, laser based gas sensors have been developed. To complement measurements from these sensors accompanying meteorological subsystems should be developed.

Meteorological Subsystems

Laser based trace gas sensing systems require real-time synchronous measurements of pressure, temperature, humidity, location (for mobile platforms), and GPS time synchronization for accurate time-stamping

Laser Spectrometer Overview

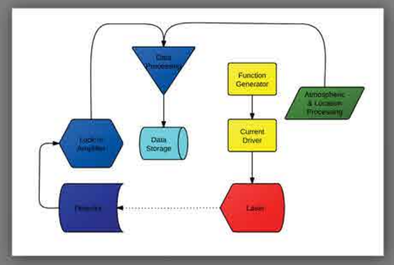

Fig 1: An overview of the laser spectroscopy system

Components of a Laser Based Trace Gas Sensor

- Laser current driver, temperature controller, and modulator
- Photodetector, data processing and storage
- Interfacing and meteorological subsystem (atmospheric & location processing)

Meteorological Subsystem Requirements

Requirements

- For mobile applications (**Use in UAVs**)
  - Compact form factor
  - Lightweight (**>500g**)
- For field applications (where grid power is unavailable)
  - Low power requirements (**<1W**)
  - Battery power (**9V**)
- For data correction and spacial sensing
  - Meteorological data acquisition
    - Temperature
    - Pressure
    - Humidity
  - Location
  - High Speed Data Output (**~10Hz**)

Fig 2: A standalone sensor in the field. Battery power and compact form factor is key in these types of applications.

Meteorological Subsystem Schematic

Sensor Array

- Pressure Sensor MS-5803
  - Low power, **1 µA**
  - **±1.5 mbar** pressure accuracy
  - I²C communications
  - **±0.8 °C** temperature accuracy
- Humidity Sensor HYT-221
  - **± 1.8%** relative humidity accuracy
  - I²C communications
  - **±0.2°C** temperature accuracy

Microcontroller

- ATmega 328 based
  - Able to output data at ~100Hz

GPS Sensor

- EM-406a
  - **5m** positional accuracy
  - **1µs** time accuracy

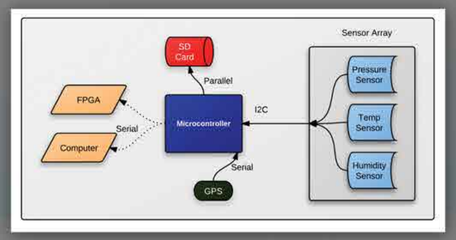

Fig. 3: Overall view of the atmospheric and location processing system. Raw data is collected from the various sensors and processed by a microcontroller. The processed data is then timestamped and stored to external memory, in this case an SD card. Optionally data can be sent over serial to a computer or FPGA system.

Construction

- Arduino based for simplicity and ease of replication
- Uses readily available parts including circuit boards
- Expandable **modular design**
- Easy to program
- Can be powered by **9V battery**
- Data stored on **SD cards**

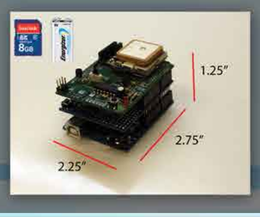

Fig 5: The assembled sensor modules along with accessories.

Fig 4: The GPS and Data-logging Module. This module contains a GPS Sensor (Beige Square) and a SD Card writer (underside)

Fig 5: The Sensor Module. This contains a humidity temperature sensor (yellow), a pressure/temperature sensor, and room for extra sensor modules.

Fig 6: The microcontroller module. This contains an arduino microcontroller, USB serial interface, DC power inputs, and voltage regulat

Field Results

Meadowlands

- QCL based N2O trace gas sensor
- Sensor used in field campaign in the NJ Meadowlands (outside NYC)
- Nitrous oxide flux from the swamp was measured
- The isolated sensor was placed inside the gas cell to measure temp. and pressure
- Because of the device's small size and robustness it was able to be placed completely within the cell
- Low poser consumption allowed the device to be powered by only a 9 volt battery

Fig 7: This atmospheric sensor had the GPS module removed and replaced with a real time clock and SD Card Writer. Pressure and Temperature data from within the cell was recorded throughout data collection.

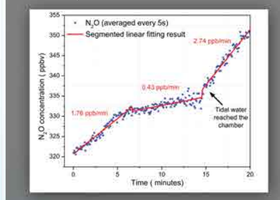

Fig 9: N20 flux measured in one of the meadowland test

Fig 8: The test site in the meadowlands.

Fig 9: The UAV that the sensor was placed on

Texas

- VCSEL based methane trace gas sensor
- A similar sensor was used in the field in Dish, TX
- Methane concentrations were measured
- Concentration data was timestamped and location data was added

Fig 10: Flightpath concentration profiles at 0-300m. Red is most concentrated, green is least

Future Work

Improvements

- Integrate more I²C sensors
- Migrate to a single board chipscale platform
- Possibly migrate from modules to a single board
- Decrease power requirements further

Integration

- Connect the meteorological subsystem to a FPGA board (Fig. 10)
- Create a hybrid board that integrates all electronics used in the laser spectroscopy system

Fig 11: The FPGA board that the meteorological system will eventually integrate with. (See poster 42 for more details)

www.mirthecenter.org