Sensing trees in Smart Cities with open-design hardware

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Introduction

Sensing in smart cities

Context:

- Monitoring the environment is a great challenge everywhere
- São Paulo has more than 650,000 trees on the streets
- People can be injured during a heavy rainfall or even when a tree falls down
- The transit can be heavily affected in case a environmental disaster happens
- The area in a range of a sensing station can be remotely monitored and evaluated to notice or even predict bad situations and prevent any further environmental catastrophes

Sensing in smart cities

With **open-design hardware** we will have:

- Components with low cost
- Easy repair or replacement
- Reproducibility

Research

Research partners:

- Instituto de Biociências (IB-USP)
- Grupo Cigarra - UNIFESP
- Centro Nacional de Monitoramento e Alertas de Desastres Naturais (CEMADEN)
- Instituto de Pesquisas Tecnológicas (IPT)

Partners' context:

- Expensive sensors available
  - IB uses the Sap Flow Meter (SMF1) that cost U$3k
  - The maintenance of 12 sensors was R$17k
  - CEMADEN stations cost more than R$10k
  - IPT sensors cost R$100k
- Many trees and places to monitor
  - São Paulo has 650k trees
  - CEMADEN monitors the whole Brazilian country
- Evaluate environment variables
  - Evapotranspiration (the sum of water evaporation and plant transpiration)
  - Weather conditions (air velocity, etc)
  - Water level

Main objectives:

- Improve existing proprietary solutions
- Make it easy to replicate
- Integrate with InterSCity platform
- Improve quality of data acquired by the sensors
- Analyze the data, create models, and help decision making for Smart City management

Related work

Une nouvelle méthode pour la mesure du flux de sève brute dans le tronc des arbres.

- A. Granier.
- Annales des sciences forestières, INRA/EDP Sciences, 1985, 42 (2), pp.193-200.

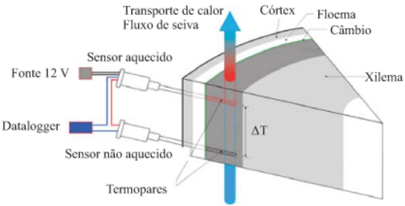


Figura 2. Esquema do sensor de Granier inserido perpendicularmente no tronco

Estimativa da transpiração em cafeeiros utilizando-se sensores de dissipação térmica

- Revista Brasileira de Engenharia Agrícola e Ambiental (2010)
- Includes a design for a calibration chamber
- Evaluated at Garanhuns - PE

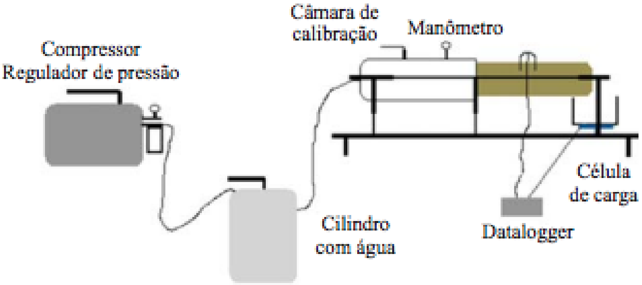


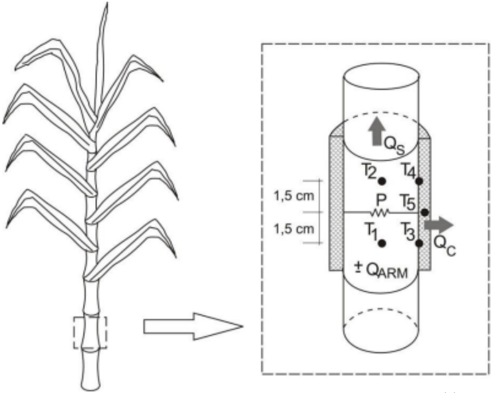
Figura 3. Representação esquemática da câmara de calibração de fluxo de seiva para simulação do fluxo de seiva

Sap Flow Sensors: Construction, Quality Control and Comparison

- Sensors journal (2012)
- Proposes an alternative to Dynamax TDP30 commercial sap flow sensor
- Uses Type E thermocouple
- 24 sensors evaluated
- Compares with the commercial alternative
- Presents different peaks

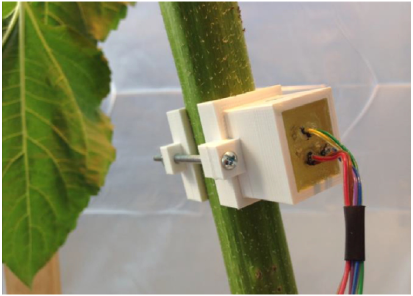
Determinação do fluxo de seiva na cana-de-açúcar pelo método do balanço de energia caulinar

- Engenharia Agrícola (2013)
- Area with 192 plants
- Evaluated at Viçosa - MG



A heat-pulse method for measuring sap flow in corn and sunflower using 3D-printed sensor bodies and low-cost electronics

- Agricultural and Forest Meteorology (2017)



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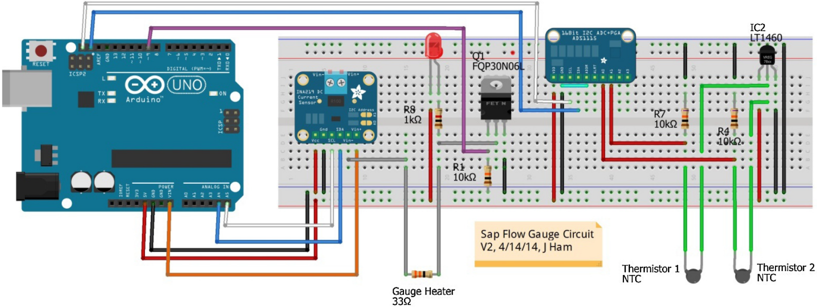
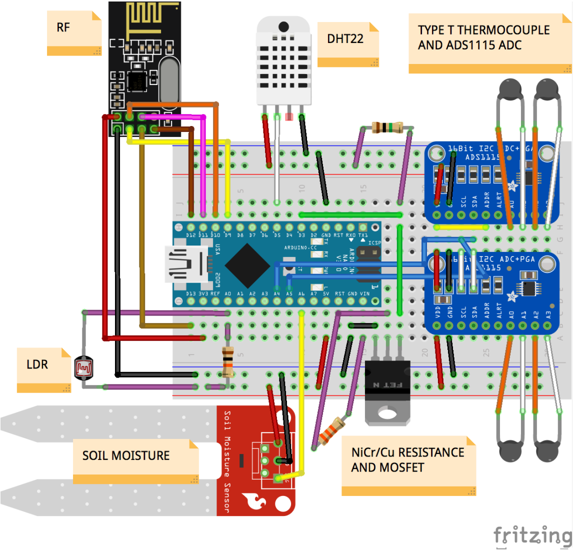


Prototype

Current prototype:

- Created by dj, Seiji, Max
- Using Arduino, ESP8266, and RF
- Includes the components:
  - Sap-flow sensor
  - Leaf temperature sensor
  - DHT (humidity and temperature)
  - LM35 (independent temperature sensor)
  - LDR (luminosity)
  - Moisture sensor

Latest prototype



Sensors available:

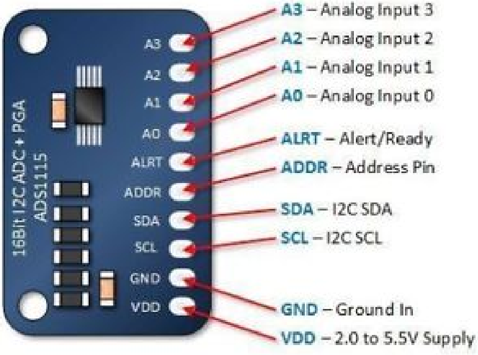
- Light
- Environment temperature
- Environment relative humidity
- Soil moisture

Additional features:

- Leaf transpiration
    - Leaves temperature
    - Air temperature
    - Soil temperature
- Sap flow measure (HPM)
    - Stem temperature
    - Heater temperature

ADS1115 ADC 16Bits (analog-to-digital converter)

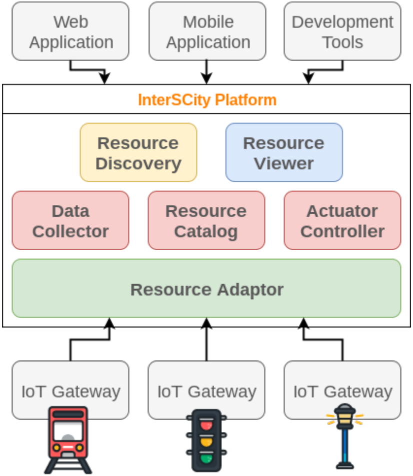
- Voltmeter
  - single ended
  - differential
  - ± 6.144 volts



Source: Henry's Bench website

Data

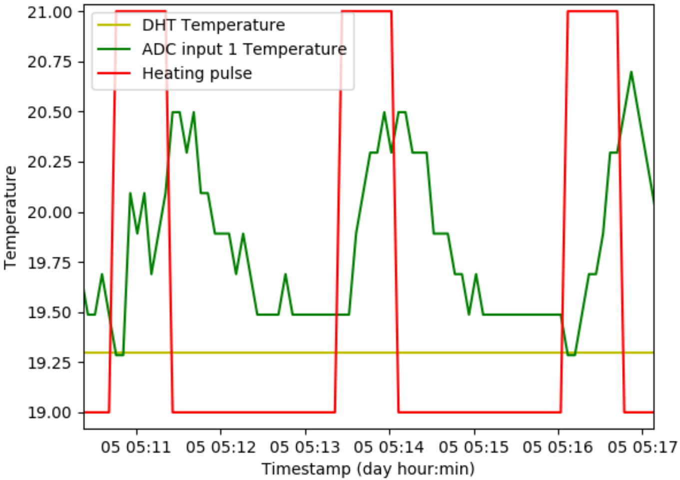
InterSCity platform architeture



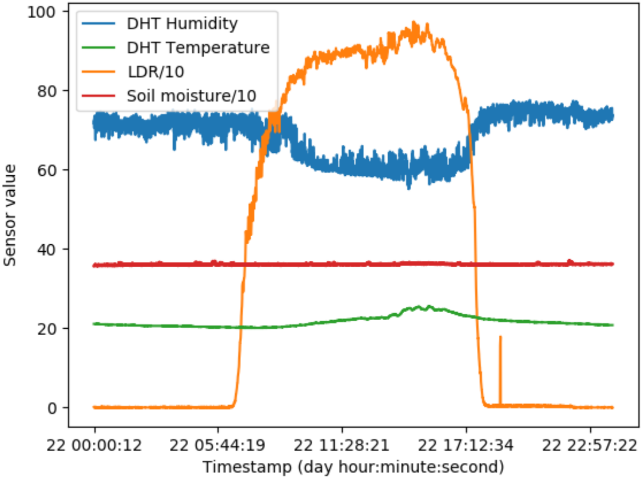
Sap flow measurements

- Sensor station:
  - LDR
  - Capacitive soil moisture sensor
  - DHT22
    - Environment temperature
    - Relative humidity
  - Four type T thermocouples
    - Upward needle
    - Downward needle
    - Heater (outside and inside the needle)
  - Two ADS1115
- Method:
  - Heat-pulse Method

Heating pulse effect on sap flow measurement



Sensors data including LDR, DHT, and soil moisture



Concluding remarks

- The prototype suits the needs for most botanical measurements
- Total price is R$ 250.00 (U$ 68.00)
- Children can mount the schematics on Arduino
- But only specialists can finish the sensors and heating probes
- InterSCity platform provides an easy-to-use setup for IoT projects

Current objectives:

- Compare the current station with other solutions available (ICT, etc)
- Compare the stations between each other considering the hand-crafted process
- Process the data through signal filters and statistical algorithms
- Create models for evapotranspiration estimation and dangerous event prediction
- Analyze time-series using deep learning techniques and find temporal dependencies
- Provide Smart City dashboard for researchers and city managers to facilitate data visualization

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gitlab.com/interscity/iotrees

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