

# Attila Géczy



## Application of Grid-Eye IR sensor for enhanced HMI and OSH purposes in Industry 4.0 reflow soldering environment

Attila Géczy, Tólas D. Mátyás, Judit Kámán, Gábor Harsányi

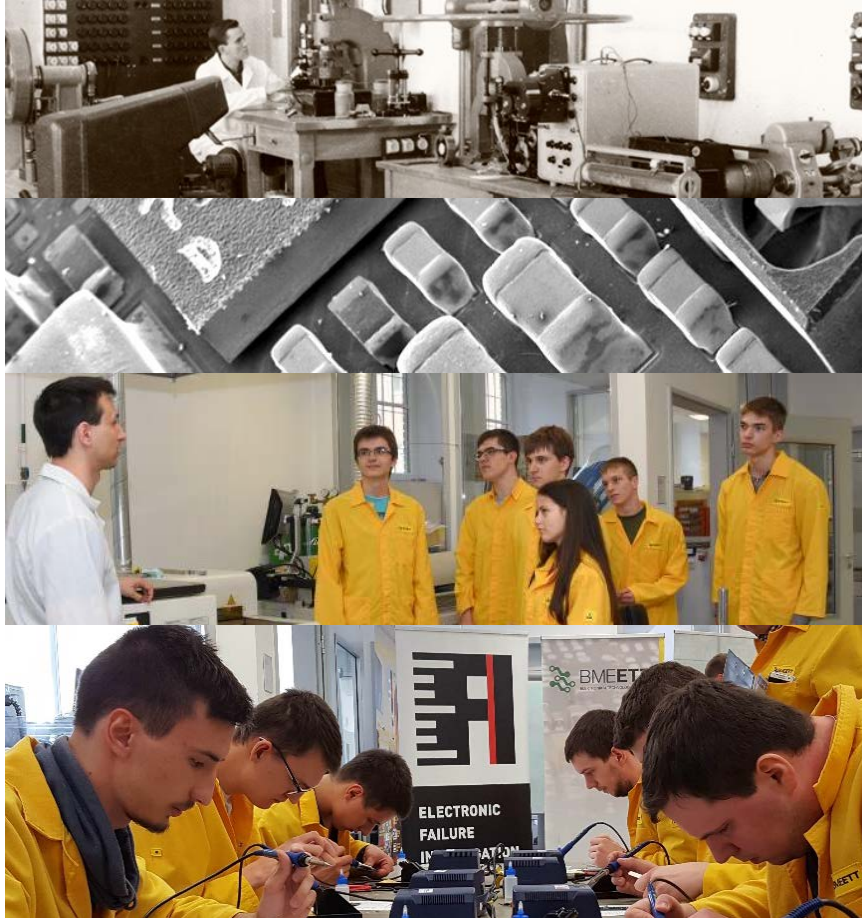
Attila Géczy is an associate professor at Budapest University of Technology, Dept. of Electronics Technology. His main fields include packaging technologies, reflow, heat transport, modelling, green electronics, applied sensors and e-education. As a commissioner for the Dean, he works on PR-related activities of the faculty. As the president of the IMAPS Hungary Chapter (subsidiary of MELT), he works on the reactivation of the chapter activities.



# THE DEPARTMENT:



- Department of Electronics Technology - since 1964



- ***electronic components, circuits and systems***
- ***interconnection and packaging technology of microelectronics circuit modules***

## OUR COMPETENCE FIELDS:

- ***PCB and circuit design & manufacturing;***
- ***CAD, modelling, simulations;***
- ***Assembly technologies: SMT, THT;***
- ***Failure investigation;***
- ***Biosensors and nanometrology;***
- ***Lasers; Thick & Thin Films;***
- ***Applied sensors;***



# INTRODUCTION:



Sensor research at our department since the 80's.

- at **Budapest University of Technology and Economics (BME)**, Hungary

THE TEAM



Prof. Gábor  
Harsányi



Attila Bonyár



Hunor Sántha



Judit Kámán

BIOSENSORS

APPLIED SENSORS



Attila Géczy



Amine Mohamed  
Alaya



Dániel  
Straubinger

## SENSOR RELATED PROJECTS:

- *Biosensors*
- *Sensor characterization*
- *Microfluidics*
  
- *Applied sensors in I4.0 manufacturing*
- *Applied sensors in automotive*
- *Wearables based on applied sensors and IoT devices*

The applied sensor research is supported by the National Research, Development and Innovation Fund (TUDFO/51757/2019-ITM) Thematic Excellence Program.

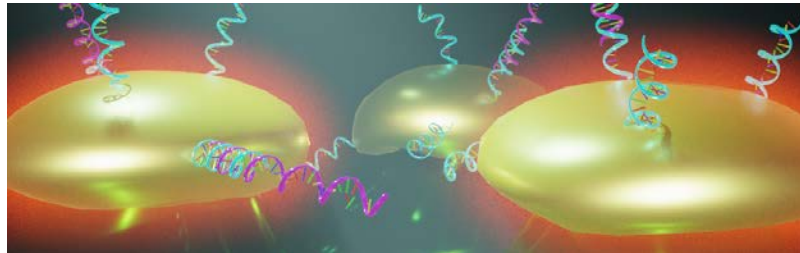
Numerous BSc and MSc students were working on the topic throughout the years.

Application of Grid-Eye IR sensor for enhanced HMI and OSH purposes in Industry 4.0 reflow soldering environment

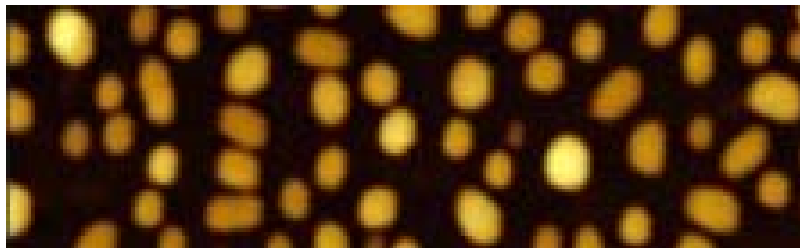
# DIFFERENT SENSOR PROJECTS:

EXAMPLES FROM OUR DEPT:

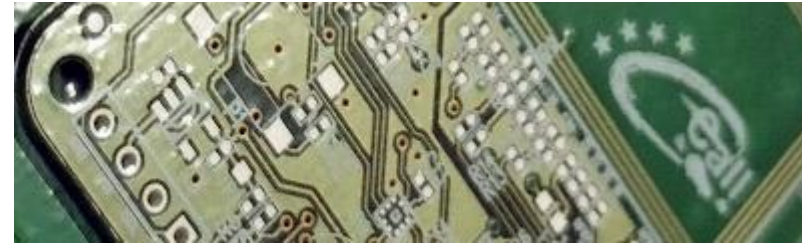
ELECTROCHEMICAL AND  
OPTICAL BIOSENSORS



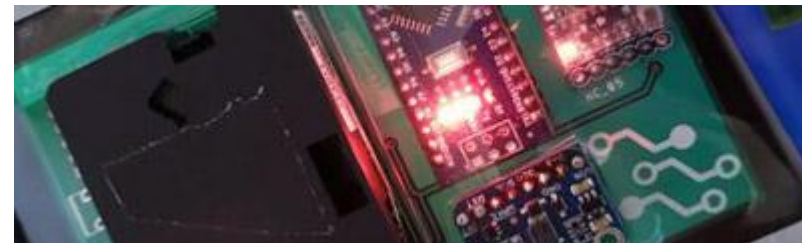
Optical nucleotide nanobiosensor



Nanofabrication, nanosensors;  
Microfluidics



Automotive HMI device for eCall purposes  
(pressure sensor – airbag detection)



Wearable cluster for air quality  
monitoring in smart labs and cities

APPLIED SENSORS,  
PLATFORMS

# MOTIVATION:

- Applied sensors point to smart manufacturing in Industry4.0.
- New applications may lead to better control and improved manufacturing quality.
- Cheap sensors, easy to develop card computer platforms with IoT compatibility.
- Path for new ideas!



- New Industry 4.0 lab environment for demonstrational purposes at the Faculty.
- Demonstration platform with ETT-competency.
- New ideas to enhance reflow soldering.

# THE IDEA:



- Enhancement of a reflow oven
- Thermal management?
- Enhanced Human-Machine Interface?
- Improved Occupational Safety and Health (OSH) aspects?
- Possibility for retrofitting?



- Better user experience and online availability;
- Control and validation;
- Additional signals for operators.
- Hot surfaces, hot surroundings of ovens. Danger!
- To apply on bench-top or in-line ovens.

## Selected examples of applied sensors in the latest literature:

Andrea Benešová, Martin Hirman, Karel Šíma, František Steiner, Aleš Hamáček, Jiří Tupa, IoT unit for reliability improvement during of the product life cycle, IMAPS Poland 2018 Conference, 23 - 26 September, Gliwice, Poland

Paul Wild, Hans Bell, Lukas Ziegler, Convection Soldering Systems in the Age of Industry 4.0 Smart Reflow Permits Predictive Maintenance - Case Study, *Rehm Thermal Systems GmbH*, February 2017

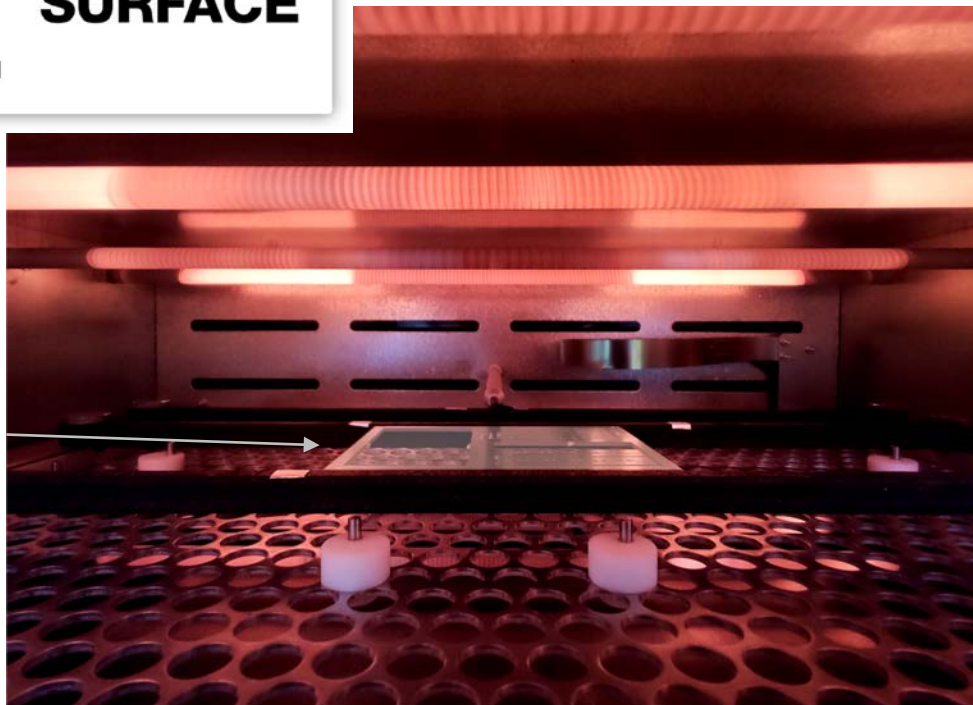
Karanjkar, N., Joglekar, A., Mohanty, S., Prabhu, V., Raghunath, D., & Sundaresan, R. Digital Twin for Energy Optimization in an SMT-PCB Assembly Line. 2018 IEEE International Conference on Internet of Things and Intelligence System (IOTAIS), 2018. doi:10.1109/iotais.2018.8600830

# ERGONOMICS:

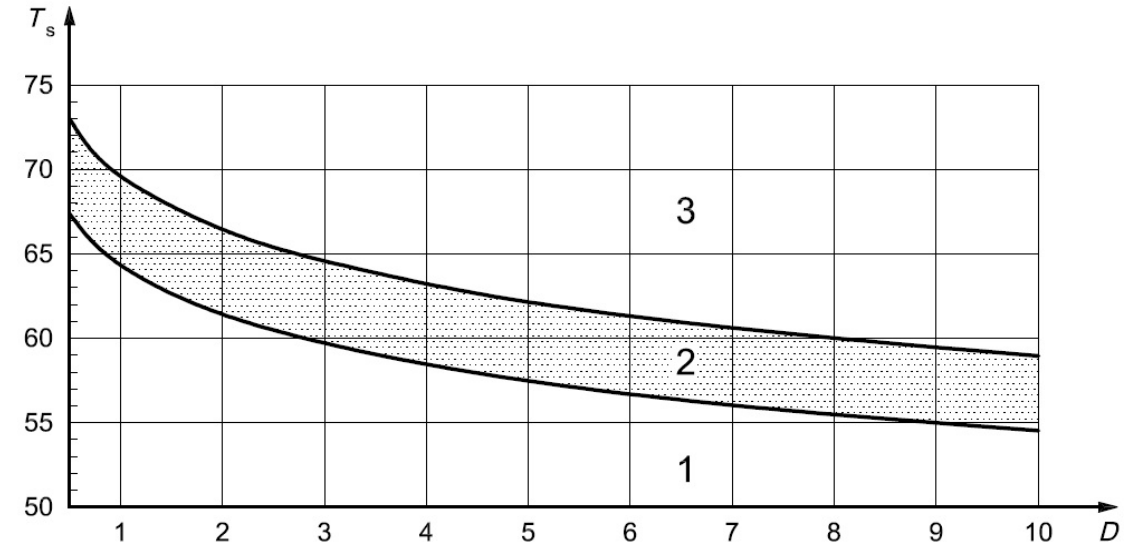


Hot workzone of an IR oven.

PCBA



ISO 13732-1:2006; Ergonomics of the thermal environment - Methods for the assessment of human responses to contact with surfaces - Part 1: Hot surfaces.

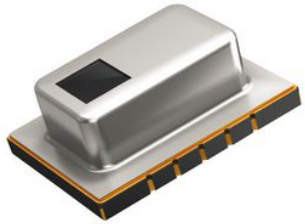


Burn threshold of a metal touched by the skin of an operator;

1 – no-burn zone; 2 – uncertain zone; 3 – burn zone;

( $T_s$ , material surface temperature [°C];  
 $D$ , contact period of skin and surface [s])

# SUGGESTED SETUP:



GRID-EYE SENSOR

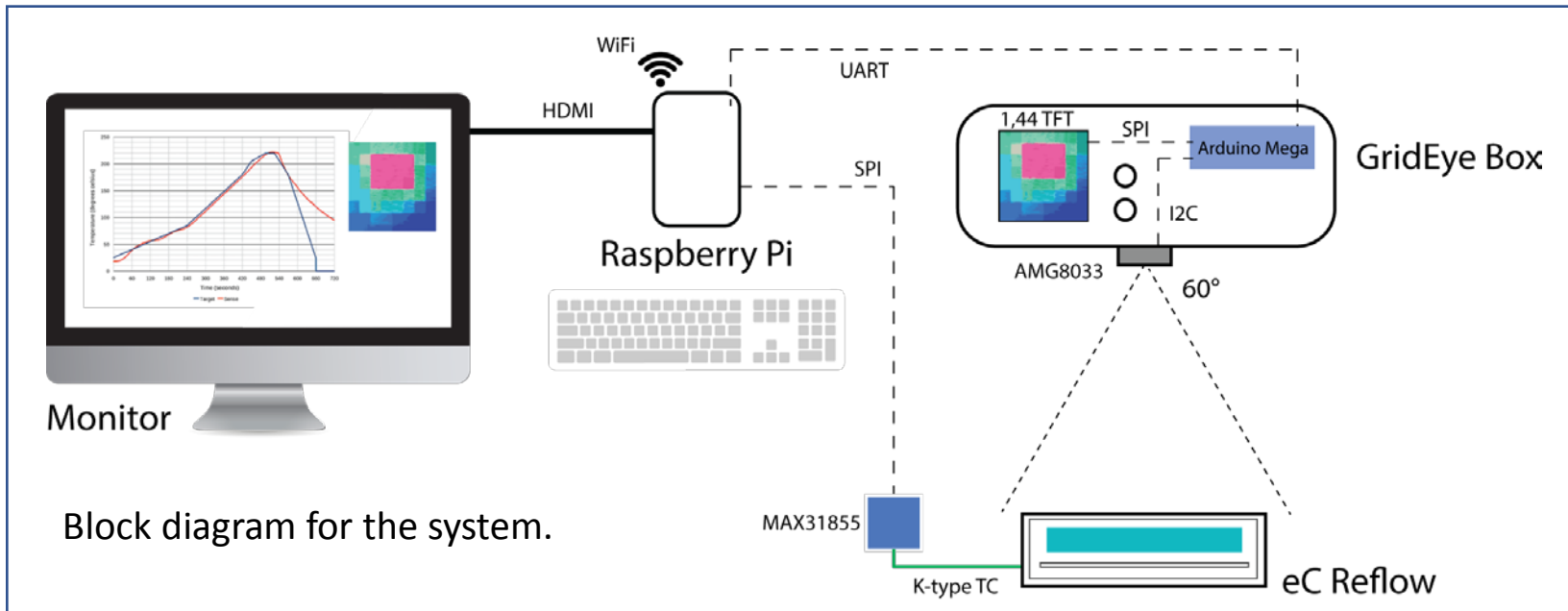


EC IR REFLOW MATE



ARDUINO MEGA & RASPBERRY PI  
CARD COMPUTERS

- Industrial, but small form-factor reflow oven
- Card computers with I4.0 focus and IoT compatibility: easy development and system integration
- Easy to setup demonstration for the capability of the sensor in HMI and OSH upgrades.





# HW SPECIFICATION:



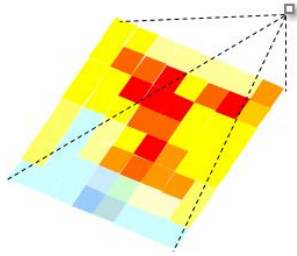
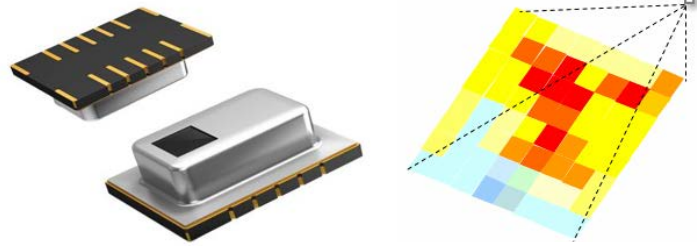
## EXACT HW COMPONENTS:

- **Eurocircuits eC Reflow Mate** oven. Bench-top form factor, infra-based heating with PC or standalone control;
- Adafruit **MAX31855 + K type** thermocouple;
- Adafruit **AMG8833**: Grid-Eye sensor breakout board;
- **Arduino MEGA**: handling AMG8833 standalone or connected mode;
- **Raspberry Pi 3.0** – Master device, with internet connectivity and web server functionality.
- Adafruit **1.44” TFT LCD** – display for standalone working of the Grid-Eye unit.

## COMMUNICATION:

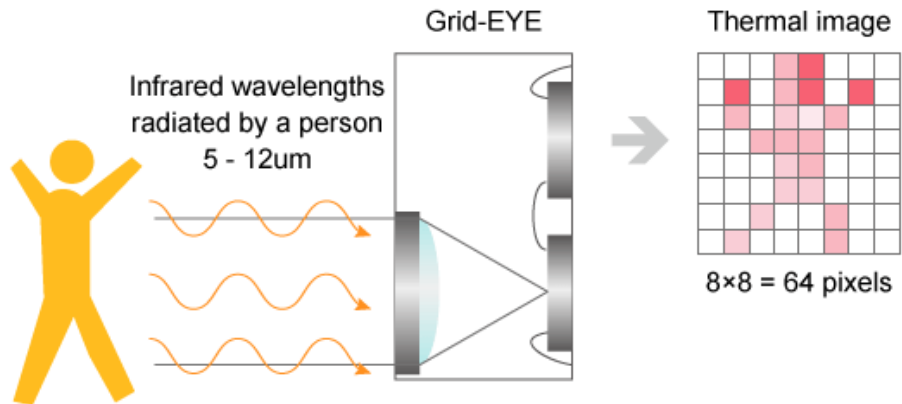
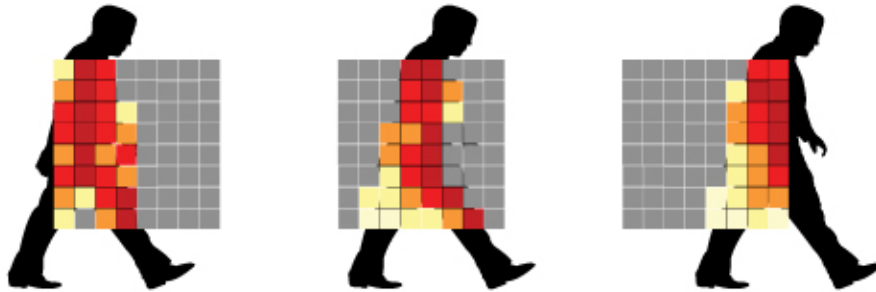
- Raspberry Pi - Adafruit MAX31855: SPI
- Arduino Mega – Adafruit AMG8833: I2C
- Arduino Mega – TFT: SPI
- Raspberry Pi – Arduino Mega: UART
- Raspberry Pi – WiFi connection to dept. Network.
- (LoRa for campus!)

# THE SENSOR

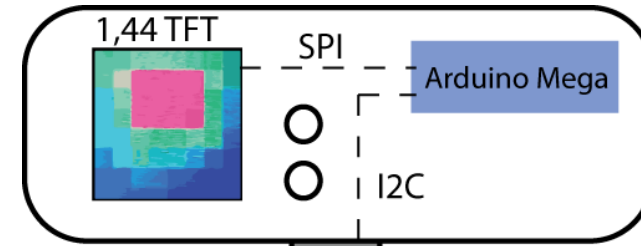


GRID-EYE SENSOR concepts

Human detection



Based on IR radiation



GridEye Box

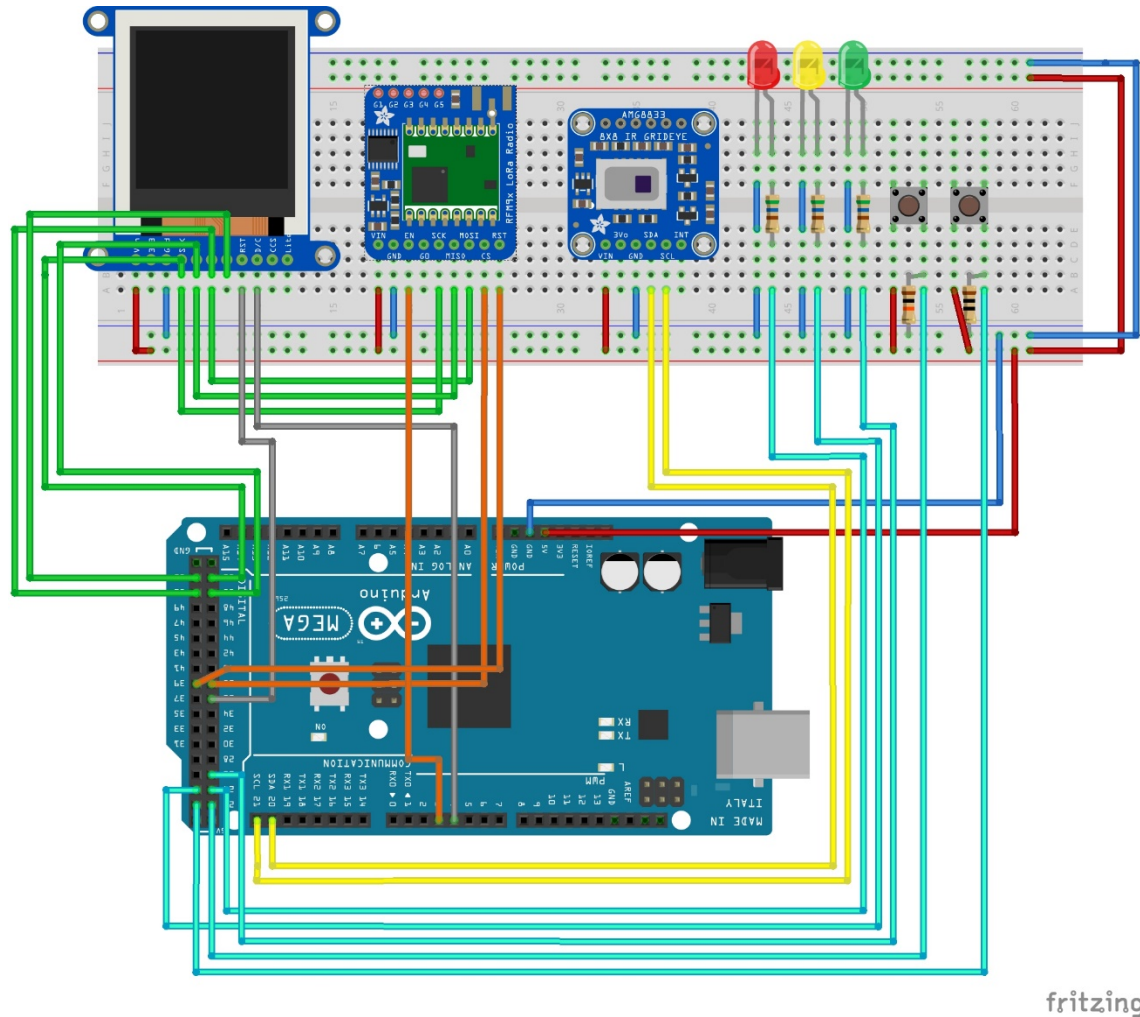
AMG8033 60°



eC Reflow

Investigated HMI and OSH submodule

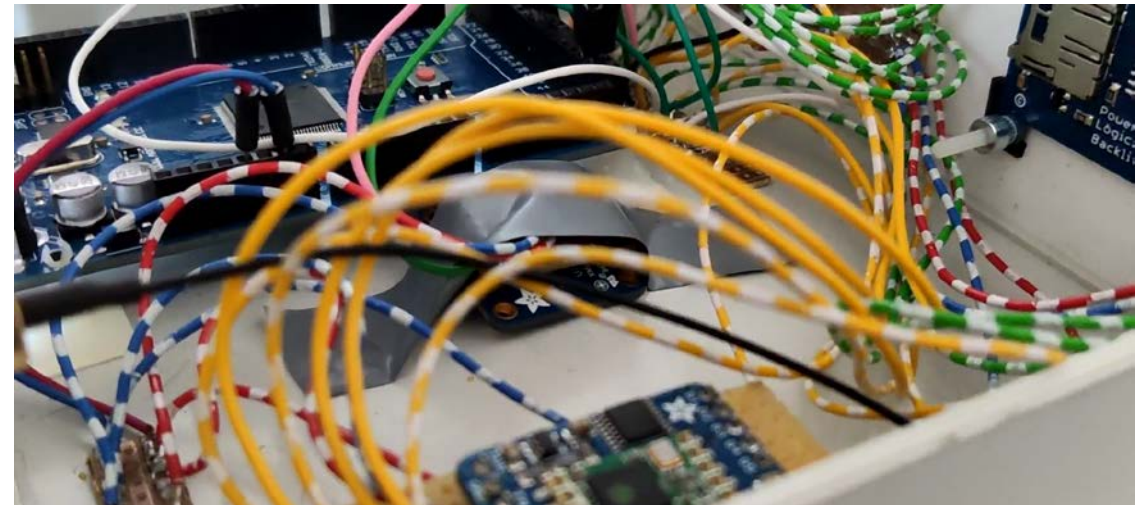
# WIRING DIAGRAM OF SUBMODULE



fritzing

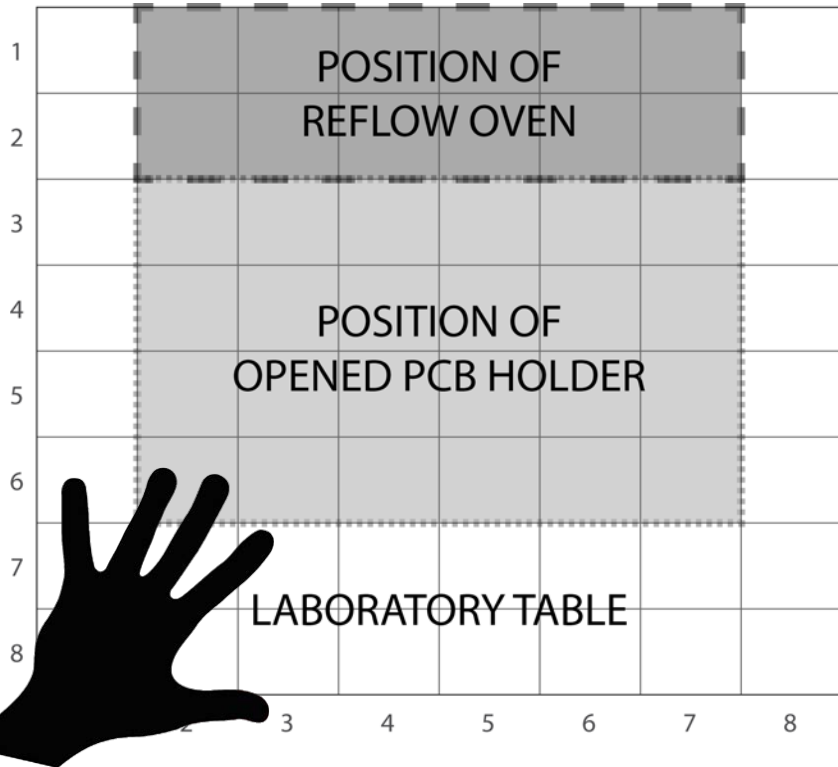
- Board prototype to boxed prototype.
- Assembled in Fritzing;
- The circuit is carried over to a packaged box version;

Arduino MEGA was required for handling standalone mode.

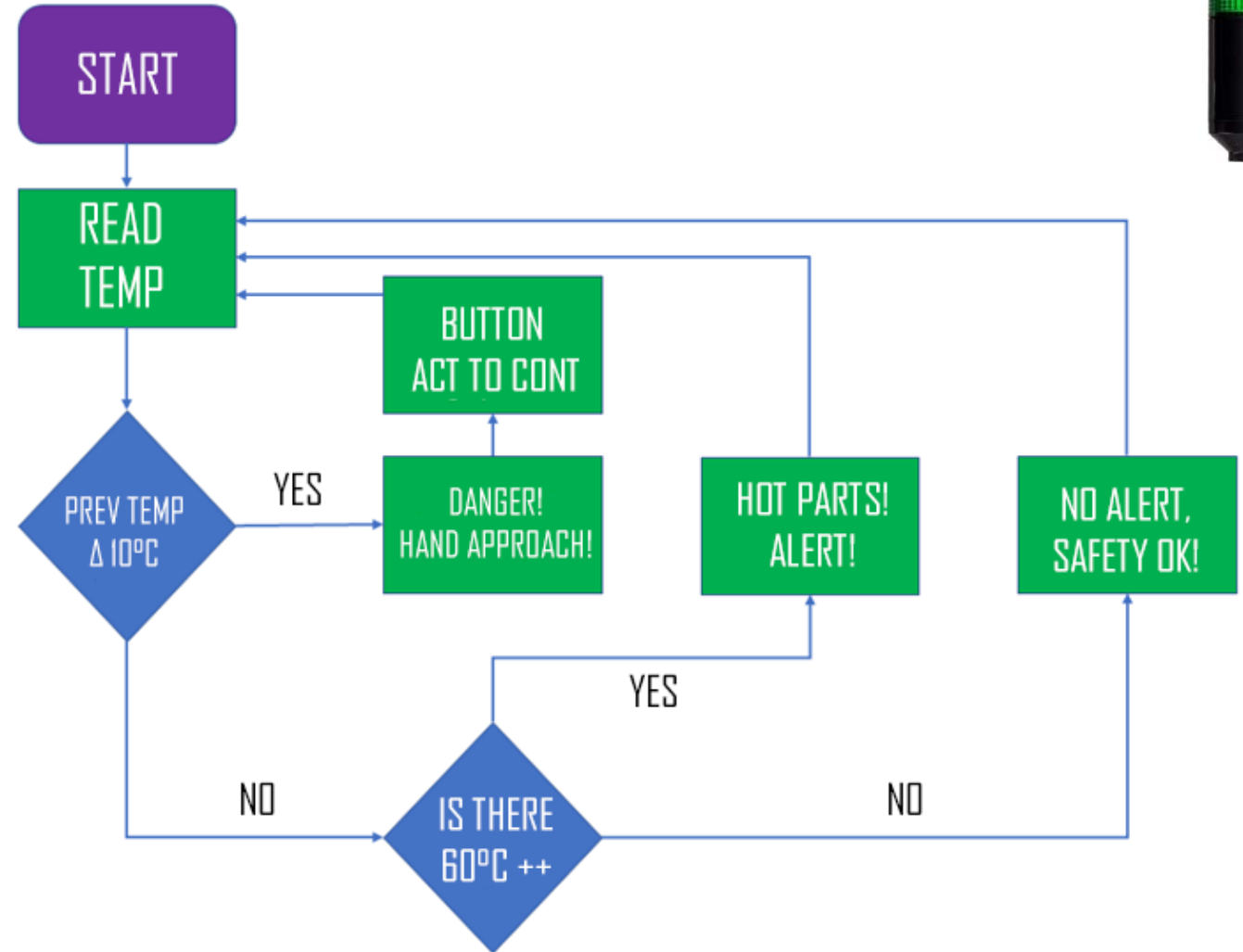


# USE CASE OF OPERATION

60x60 cm view



7,5x7,5 cm per pixel



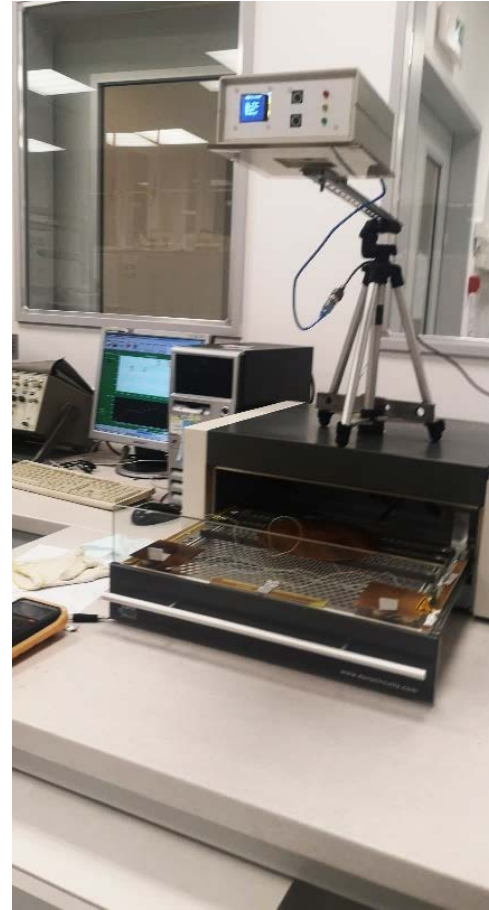
# ACTUAL TEST SETUP IN LAB ENVIRONMENT

GridEye Box

Sensor FOV

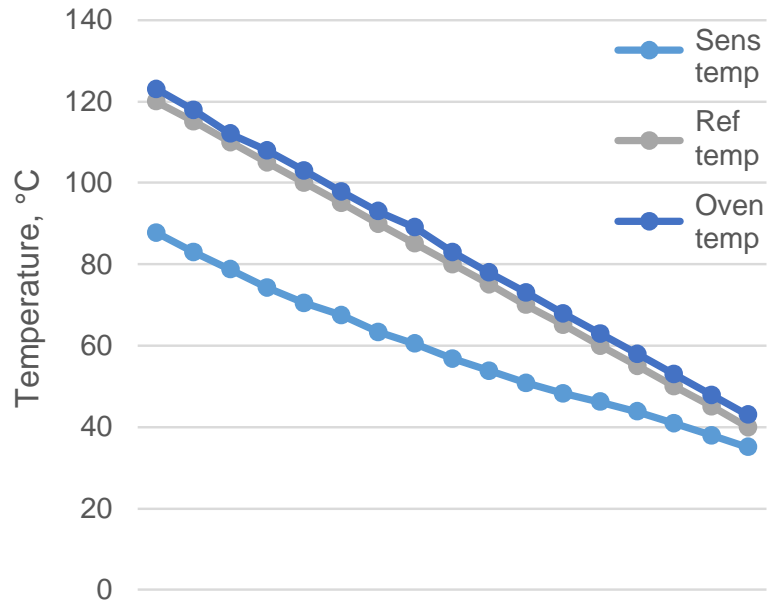
Box mount

Reflow oven with opened holder



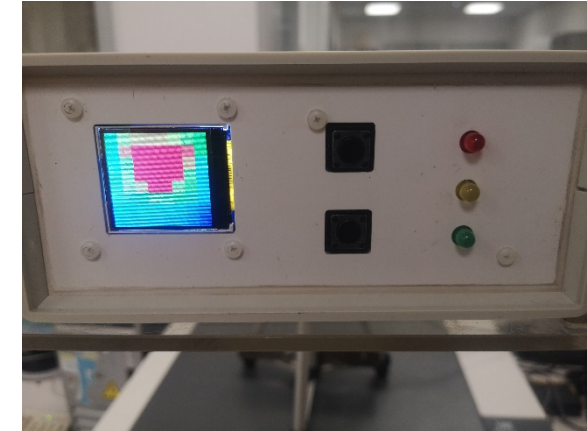
View on the system from the operators point. Note the green line – increased temperature of oven!

# VALIDATION



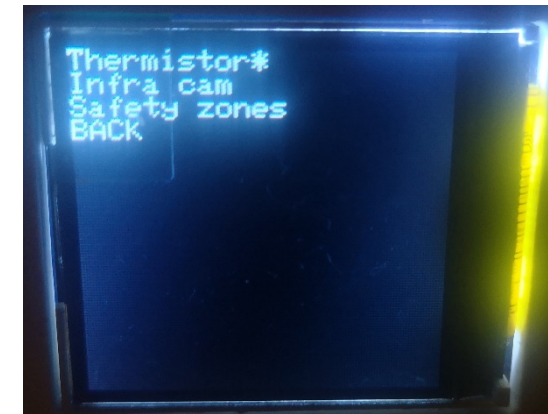
Validation of temperature values at reference temperatures. (120 -> 40 °C in 5 °C steps) on the surface of a PCB after opening of the oven;

"Sens" – GridEye data, "Ref" – reference K-type thermocouple, "Oven" – data recorded by oven thermocouple

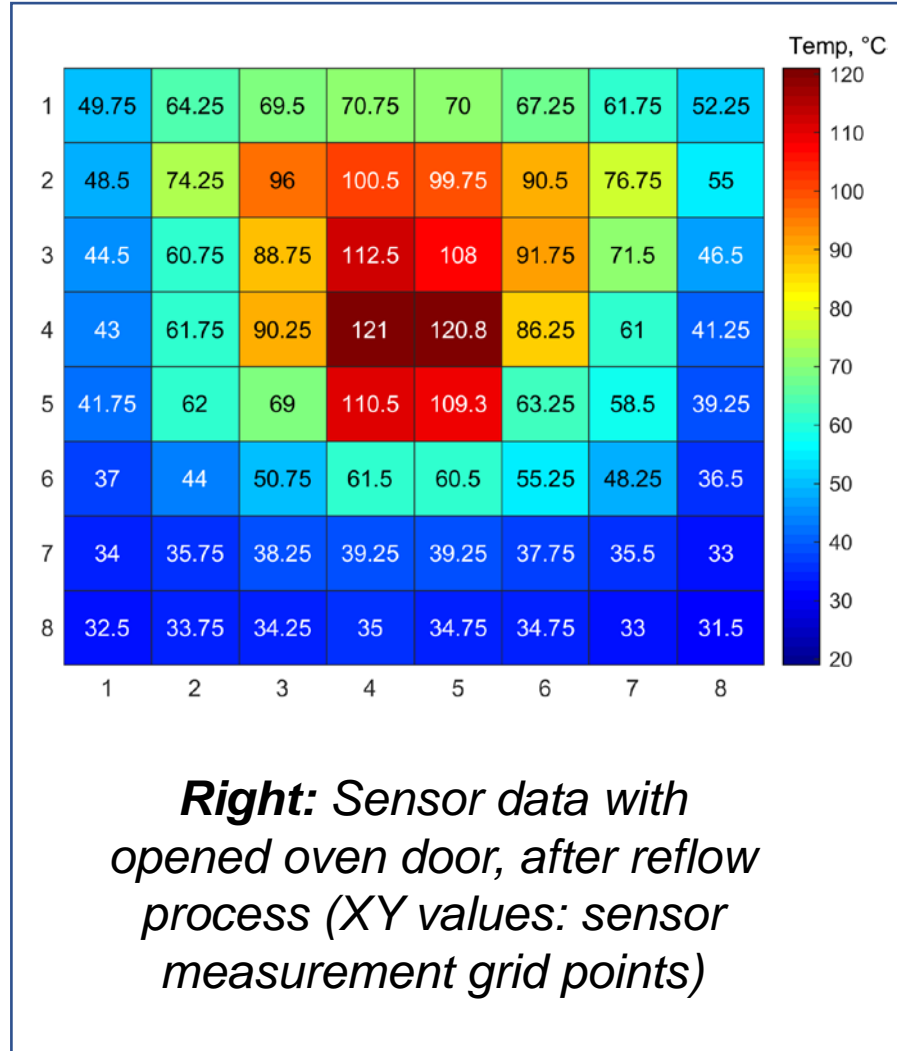
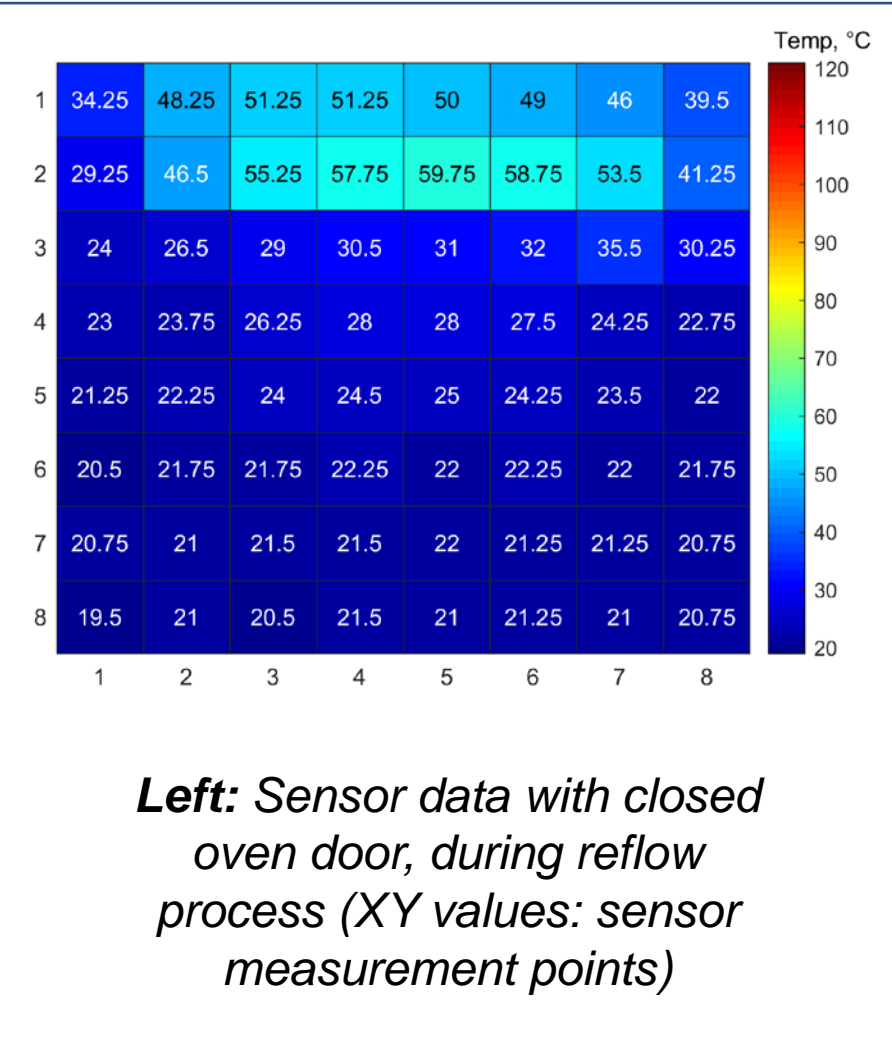


Opened and closed oven doors, highlighted by the hot zones on the display.

Standalone mode options and operational menu.

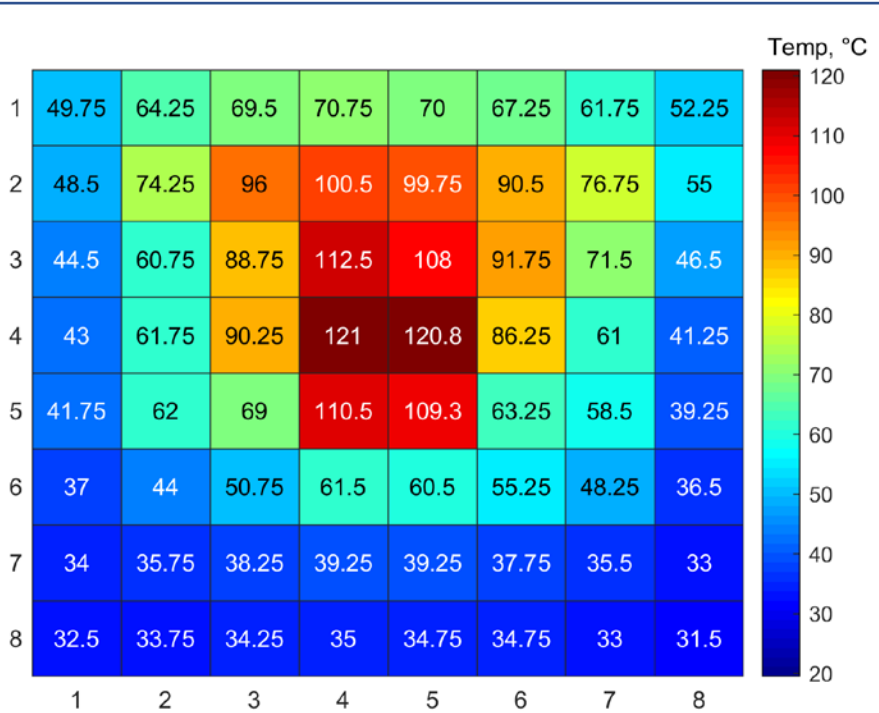


# RESULTS:

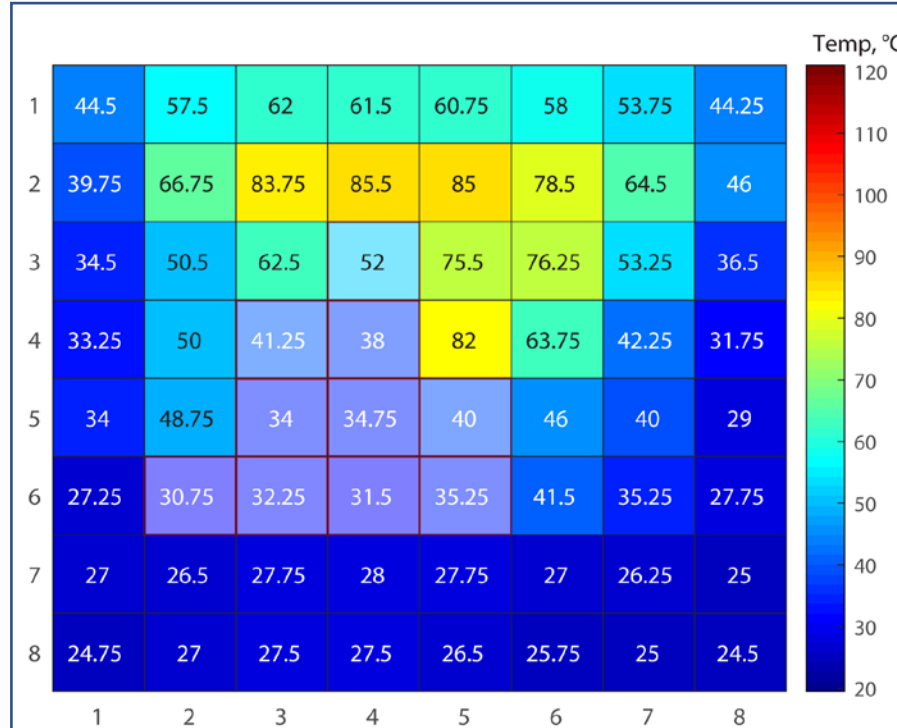


- **Conclusions for application:**
- Successful identification of closed oven separated from laboratory ambience
- Successful identification of opened door and PCB load on the shelf.

# RESULTS:



**Left:** Sensor data with opened oven door, after reflow process (XY values: sensor measurement grid points)

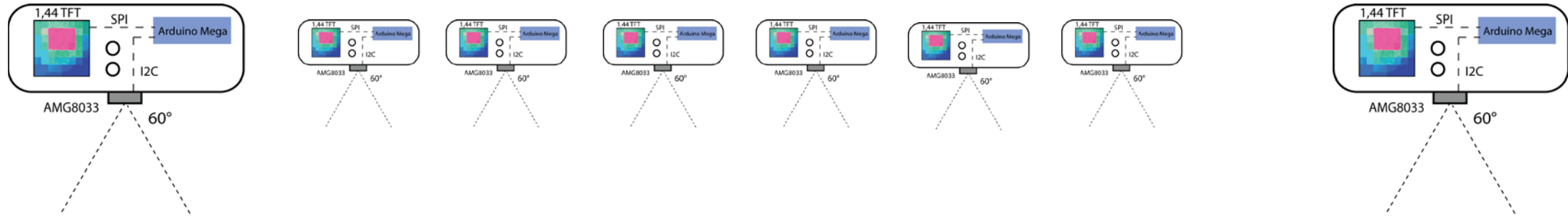


**Right:** Sensor data with opened oven door, after reflow process (XY values: sensor measurement grid points)

- **Conclusions for application:**
- Successful identification of arriving hand.
- Absolute temperature values are not reliable, however overall changes are quantitatively useful.

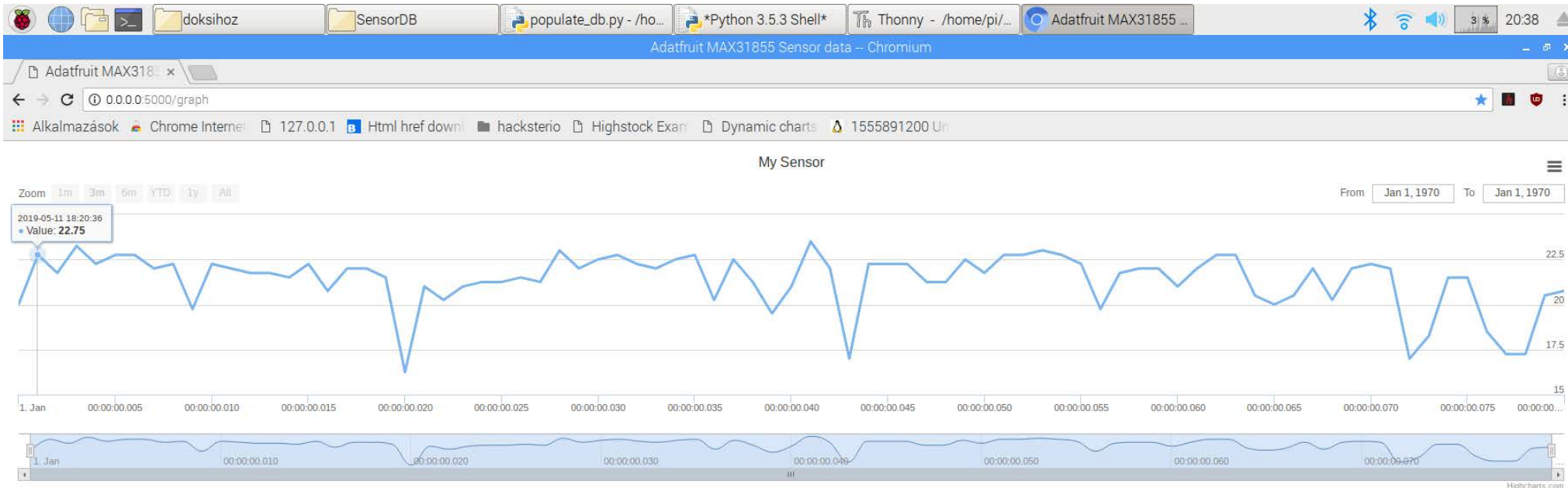


# POSSIBLE FUTURE APPLICATIONS?



Picture source: Faroadsmt.com

# WEBSERVER ON RPI



@2019 Developed by Attila

- Monitoring real time reflow temperatures
- Monitoring HMI & OSH feedback
- Observable even from a mobile phone.

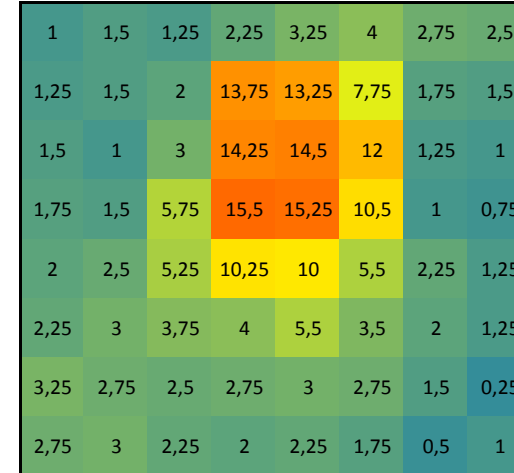
Attila Hannos: Expanding the sensor system of a reflow oven according to Industry 4.0 directives, MSc Thesis

# FURTHER APPLICATIONS OF GRID EYE AT BME-ETT

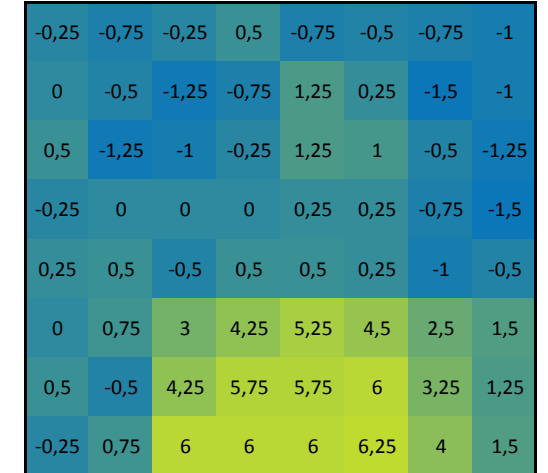


Passenger detection in cars.

Test during wintertime.



**Left:** Seated passenger



**Right:** Empty seat after driving

Ricardo de Jorge Melgar -  
Investigations on IR Sensors For  
Detecting People In a Car, BSc Thesis

# CONCLUSIONS:

The presented Grid-Eye application offers HMI and OSH functionality extension in the mindset of Industry 4.0, for reflow soldering.

With the applied sensor and control box, it is possible to differentiate the oven, the PCB holder (with possible PCBA load in alignment with the cells in the grid) and any obstruction larger than a cell (e.g. an approaching cold hand).

**Safer work and immediate feedback on the state of the process.**



**ACKNOWLEDGEMENT:** The applied sensor research is supported by the National Research, Development and Innovation Fund (TUDFO/51757/2019-ITM) Thematic Excellence Program.

# FUTURE?

- Industry4.0 readiness?
- IoT readiness?
- Additional sensors?
- Mobile application integration for complete reflow monitoring?