DIGITAL MANUFACTURING ON A SHOESTRING

Creating digital solutions that work for manufacturing SMEs

dmS | Hackathon

26 – 27 October 2019

Pitch-In

A·N·D

GIRONEX

WARREN SERVICES

UNIVERSITY OF CAMBRIDGE
Department of Engineering

DIGITAL MANUFACTURING ON A SHOESTRING
Creating digital solutions that work for manufacturing SMEs

IfM MANAGEMENT TECHNOLOGY POLICY

Agenda

Saturday 26 October

Time	Event
8:00 – 8:30	Registration
8:30 – 9:00	Kick-off: Teams gathering
9:00 – 12:30	**Hackathon Goal 1:** • Initial problem statement, constraints and functionality. • Concept sketches and rough plan.
12:30 – 13:30	Lunch
13:30 – 17:00	**Hackathon Goal 2:** • Proof of concept with initial functionality.
17:00 – 18:00	Dinner
18:00 – 19:30	**Hackathon Goal 3:** • Plan for next day, tutorial draft, teams wrap up • End of Day 1.

Sunday 27 October

Time	Event
9:00 – 12:30	**Hackathon Goal 4:** • Finish the prototyped system with full functionality.
12:30 – 13:30	Lunch
13:30 – 16:30	**Hackathon Goal 5:** • Validation and testing, documenting failures and mitigation → presentation, finish tutorial (ideally teams divide responsibilities).
16:30 – 18:00	**Afternoon Refreshments** **Judging and Awards** • Elevator pitch 3 minutes. • 3 minutes questions per team. • End of Day 2.

26-27 October, 2019

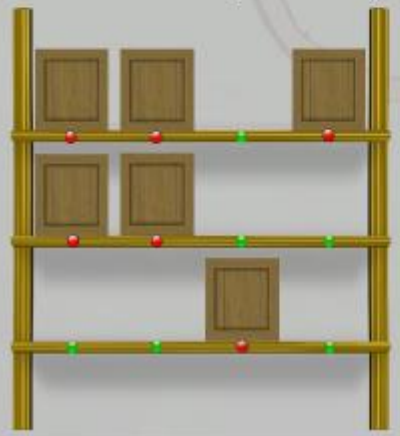
Shelf Occupancy Sensor System

Challenge:

Develop a bolt-on system to track occupied bays in an inventory system

Inventory management is an area where many manufacturing SMEs believe they could benefit from the use of digital technology.

Participants will develop a low-cost system that can detect whether a bay in a shelf is occupied. The system must be able to attach to an existing shelving setup (without modifying the shelves).



There are two phases to the challenge:

1) Provide visual feedback of shelf occupancy

2) Make shelf occupancy data and a list of item added/removed events available over the network

Evaluation Criteria:

- Total system cost
- Flexibility of detection
- Non-intrusiveness

Background and Motivation

Inventory management is an area where many manufacturing SMEs believe they could benefit from the use of digital technology. Advantages include:

- **Reduced Waste** - Better visibility of stock shelf lives (ensures products don't spoil while sitting on the shelf)
- **Improved Lead Times** - Enable better production planning in order to reduce the risk of production delays due to insufficient consumables or raw materials (especially important for time sensitive processes such as food production where delays can lead to scrap)
- **Time Savings** - Less time spent looking for stock that "must be here somewhere"

Background and Motivation

Given these benefits, it is not surprising that many SMEs have inventory management systems, even if many of those systems are mostly manual. The “cost” of an inventory management system is the time and effort it takes to keep it up to date (and an out-of-date inventory system is almost worse than none at all). This is where digitalisation can help. If digitalisation can make it quicker and easier to maintain an accurate and up-to-date inventory system, then employees can put more time and effort into actual production.

Many commercial inventory management systems are available. Some of these systems simply contain a representation of the inventory state in digital form, with all of the input and tracking is still performed manually. Other systems are more advanced and use barcode stickers or RFID tags to identify stock. To track where stock is stored, a barcode is often placed at each storage location. These barcodes are then scanned after each piece of stock is scanned so that the system knows where it is stored.

Background and Motivation

In this challenge, participants will develop a low-cost system that:

- can detect and indicate when a bay in a shelf is occupied
- could then be integrated into a commercial inventory management system to provide added functionality

The benefit of such a system is two-fold:

- it could simplify finding a place to store stock by showing which bays are available
- it could simplify stock tracking as the stock could be scanned once and then placed on a shelf and the system would be able to detect where

Scope

- The system must be able to attach to an existing shelving setup (without modifying the shelves).
- The system should make shelf occupancy data available over the network (e.g. xml over HTTP).
- The system does not need to be integrated into an existing inventory management system.
- Teams will need to decide on the constraints of their system i.e. the size of the bays, the size of stock, whether stock can be placed on top of, or in front of other stock. This part of the challenge is intentionally left open ended as it is expected that teams will need to decide on a compromise between the flexibility of their system and the cost/intrusiveness.

Judging Criteria

Teams will be evaluated based on three things:

- Their developed system prototype
- A short 3 minute presentation on their design
- A short (1-2 page or video) tutorial that could be used by an SME to implement their design

The system prototypes and designs will be judged based on four criteria:

- **Total system cost** (The system should be as affordable as possible)
- **Flexibility of detection** (The system should be able to reliably handle as many different storage options as possible)
- **Non-intrusiveness** (The system should not make it harder to store stock on the shelves)
- **Reliable detection** (The system is expected to correctly detect stock)

Any additional features or functionality will also be considered

Rules

- Teams may think of ideas and approaches as well as do research before the hackathon. However development of the system may not be done beforehand.
- Teams may use screws, etc. to attach their solutions directly to the shelves (for time saving sakes) however they must provide a design for how the system could be attached in a non-permanent way (clamped, etc.)

Provided Equipment

- Raspberry Pi 3B+
- Arduino Uno Wifi R2
- Sensors:
  - Force sensors
  - IR and Ultrasonic distance sensors
  - Limit switches
  - Beam break sensors
  - Hall effect sensors
  - Light dependent resistors
- Mechanical components
  - Springs
  - Magnets
- Electrical components
  - Resistors, etc
  - LEDs
  - Breadboards
- Wooden Shelves
- Assorted Brackets

If there are any additional sensors that you think you could use to make a better solution, please let us know asap and we will see what we can do to help

Possible Approaches

- Mechanical (lever) systems actuated by boxes
- Distance between sensor and stock
- Measuring weight on shelves
- Detecting shadows using light sensors
- Computer Vision (see the possible approaches for the “Getting Data from Legacy Control Panels” challenge)

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Hands Free Digital Drawing Navigation

Challenge:

Develop a system that will enable an operator to navigate an engineering drawing using their voice

Many SMEs are looking to move from printed drawings to digital drawings to reduce paper usage and ensure that workers always have the latest revisions. However, interacting with a digital system while working can be a challenge, especially for jobs, like welding, where the worker is wearing protective clothing, such as gloves.

Participants will develop a low-cost system that uses an open source voice assistant to convert workers voice commands into navigation instructions for a drawing viewer program.

There are two phases to the challenge:

1) Use voice commands to send web requests to a computer

2) Convert web requests into navigation instructions

Evaluation Criteria:

> Reliability of command detection

> Ease of interaction

Background and Motivation

- Many SMEs are looking to move from printed drawings to digital drawings to reduce paper usage and ensure that workers always have the latest revisions.
- Interacting with a digital system while working can be a challenge
- This is especially true for jobs, like welding, where the worker is wearing protective clothing, such as gloves.
- Participants will develop a low-cost system that uses an open source voice assistant to convert workers voice commands into navigation instructions for a drawing viewer program.

Scope

- Electronic drawings are typically provided as PDFs and viewed using standard PDF software or as DWG files and viewed using an engineering drawing viewer.
- At a minimum, a worker would need to:
  - Zoom in and out
  - Pan around the drawing
  - Consider the other features that a worker might require and try to implement them (e.g. next page, make a note)

Judging Criteria

Teams will be evaluated based on three things:

- Their developed system prototype
- A short 3 minute presentation on their design
- A short (1-2 page or video) tutorial that could be used by an SME to implement their design

The system prototypes and designs will be judged based on three criteria:

- **Reliability of command detection**
- **Ease of interaction**
- **Types of possible interaction**

Any additional features or functionality will also be considered

Rules

- Teams may think of ideas and approaches as well as do research before the hackathon. However development of the system may not be done beforehand.
- Ideally, all parts of the solution should work offline

Provided Equipment

- Raspberry Pi 3B+
- Headset with Microphone

If there are any additional equipment that you think you could use to make a better solution, please let us know asap and we will see what we can do to help

Possible Approaches

Voice Interaction:

Raspberry Pi Focussed:

- Mycroft
- Kalliope
- Jasper

General Focus:

- Stephanie
- Open Assistant
- Dragonfire
- Jarvis

Possible Approaches

Drawing Interaction:

- Hook into APIs of PDF or engineering drawing viewers
- Intermediate web server that generates key presses corresponding to shortcuts in PDF or engineering drawing viewers

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Getting Data from Legacy Control Panels

Challenge:

Develop a portable bolt-on system that can extract status information from legacy control panels

Many SMEs have key pieces of equipment that do not provide interfaces for digital data extraction. This equipment presents data through dials, lights and displays on the equipment's control panel.

Participants will develop a low-cost system that can be attached to a control panel to extract the data presented on the control panel and make it available in a digital format

There are two phases to the challenge:

1) Make status data available on the network

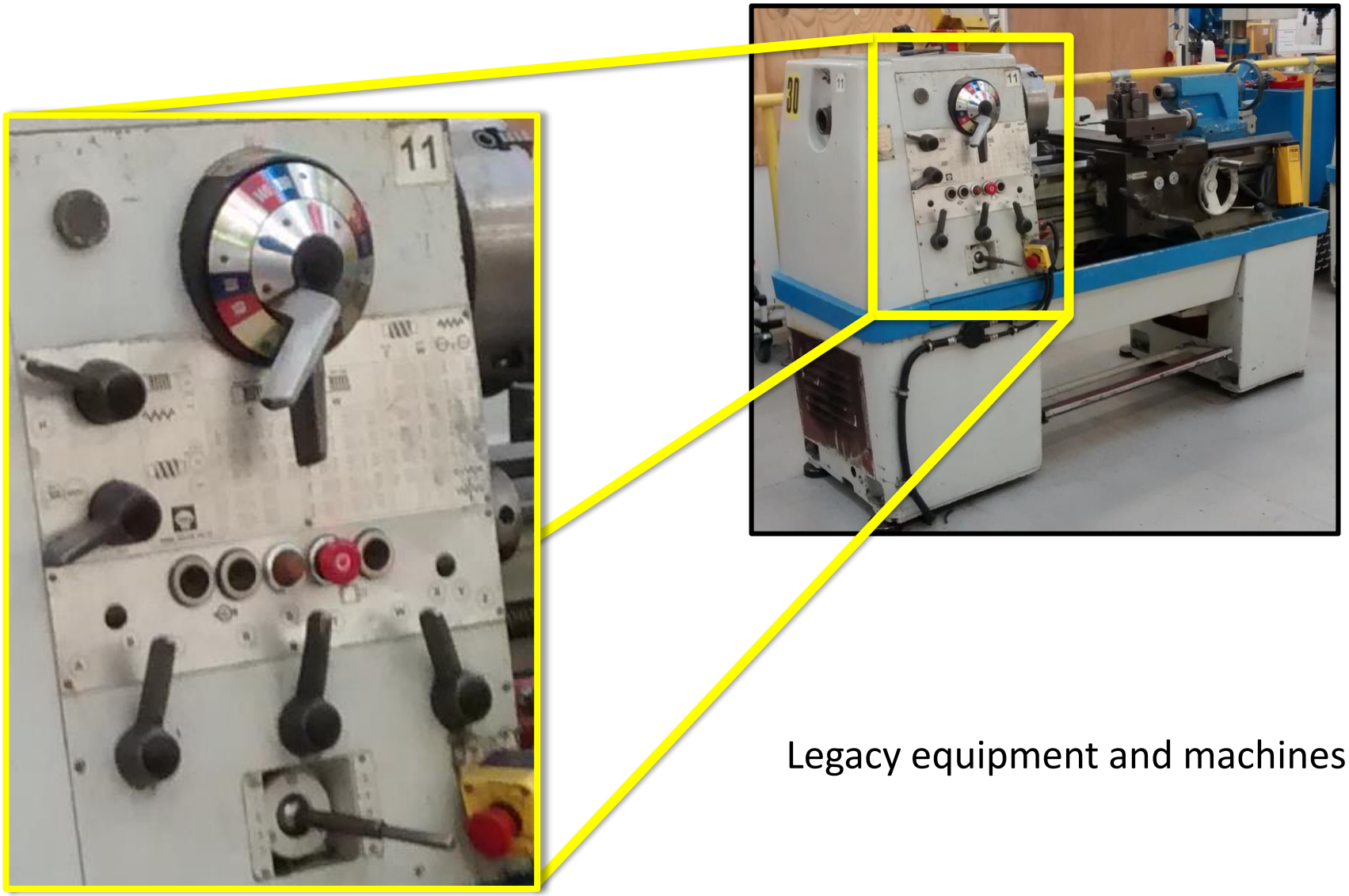
2) Send alert emails when a specified fault condition occurs

Evaluation Criteria:

- Total system cost
- Accuracy of detection
- Non-intrusiveness

Background and Motivation

- Where do you find this?
  - Shopfloor legacy machines where operational conditions are set manually
  - Cabinets purposed built to control onsite equipment
  - Dangerous zones where specific personnel or personal protection equipment is required
  - Difficult to access or remote areas within manufacturing facility
- When is it needed?
  - Operational conditions must be continuously monitored and integrated with other processes
  - Specific conditions are needed for triggering alarms or other type of alert signals



Legacy equipment and machines

Whisky distilleries

Background and Motivation

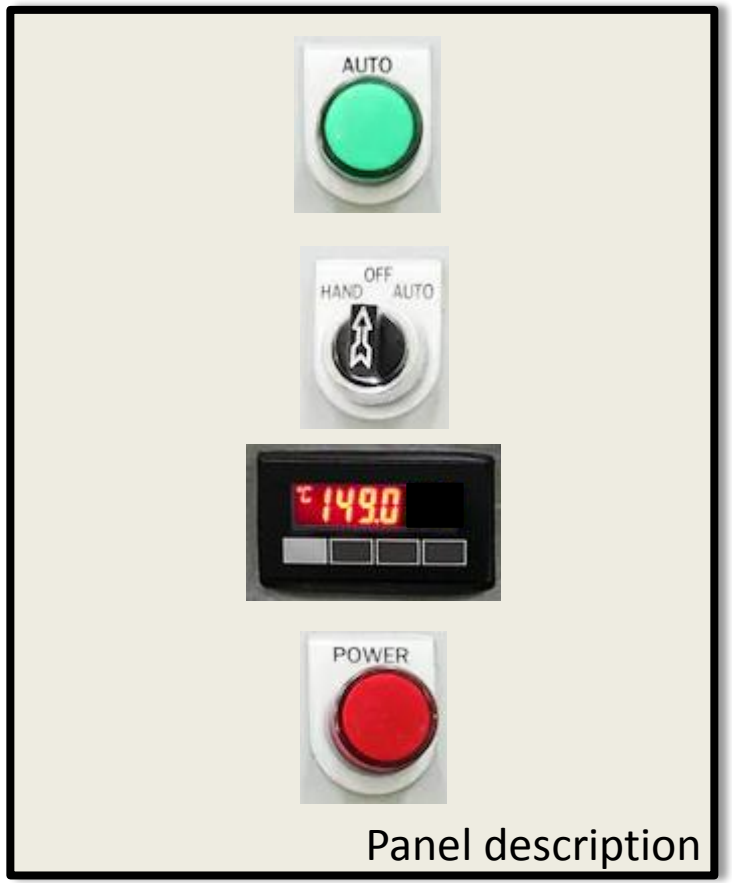
Elements for Control Panels

Lit/unlit buttons

Digital displays

Position buttons

Push buttons

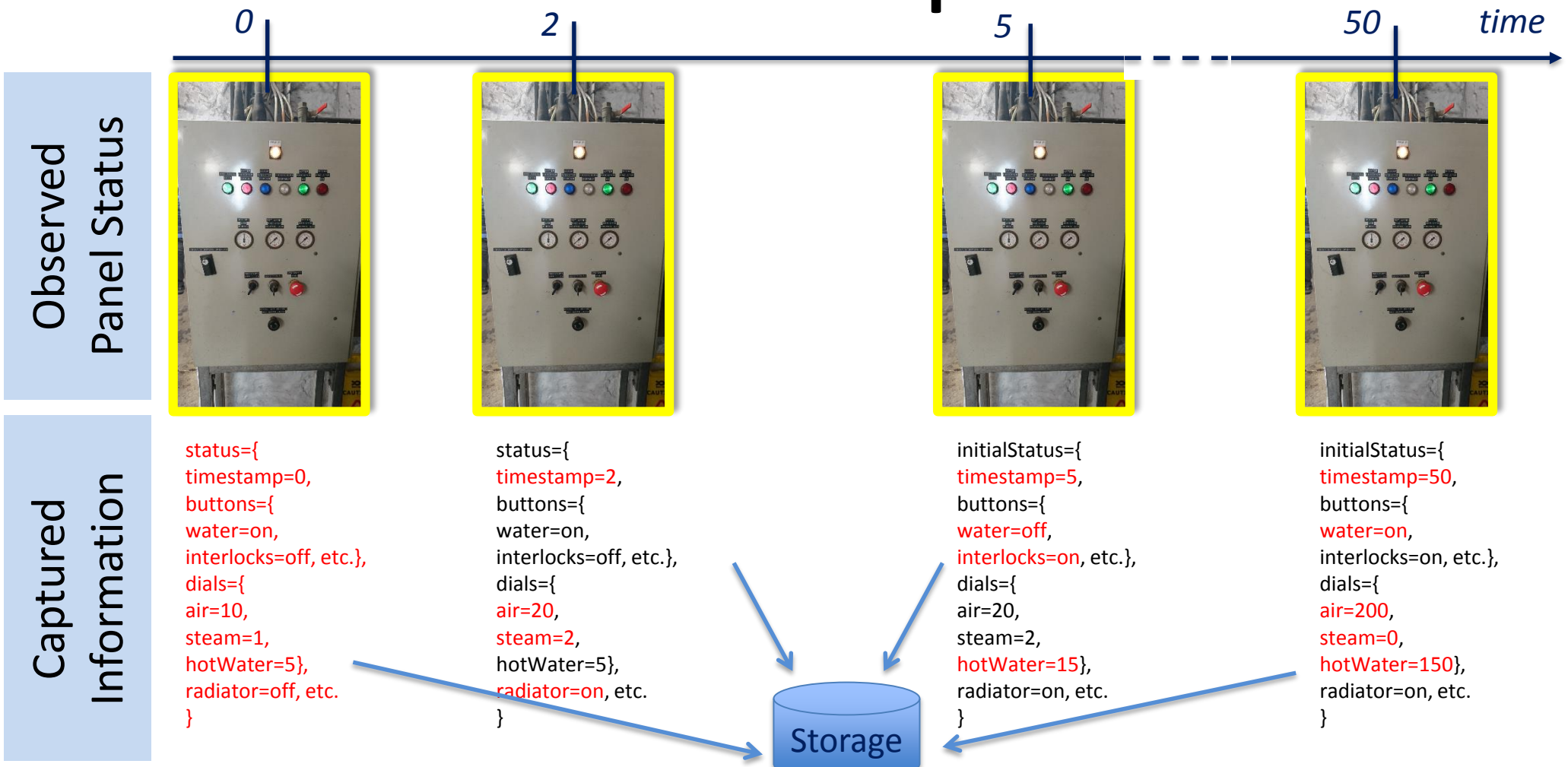


Panel description

Scope

- Only one specific panel to deal with
- Different types of control elements
- More than one occurrence per control element
- Control elements could change status automatically or manually
- Ambient light, shades, temporal occlusion (people getting on the way), points of view, etc.
- Realistic reading distances when gathering panel information
- Accuracy of control elements information is important
- Status changes should be captured efficiently and timely
- The system should make captured information available online or offline

Example


0
2
5
50
time
Observed Panel Status
Captured Information
status={
timestamp=0,
buttons={
water=on,
interlocks=off, etc.},
dials={
air=10,
steam=1,
hotWater=5},
radiator=off, etc.
}
status={
timestamp=2,
buttons={
water=on,
interlocks=off, etc.},
dials={
air=20,
steam=2,
hotWater=5},
radiator=on, etc.
}
initialStatus={
timestamp=5,
buttons={
water=off,
interlocks=on, etc.},
dials={
air=20,
steam=2,
hotWater=15},
radiator=on, etc.
}
initialStatus={
timestamp=50,
buttons={
water=on,
interlocks=on, etc.},
dials={
air=200,
steam=0,
hotWater=150},
radiator=on, etc.
}
Storage

Judging Criteria

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Any additional features or functionality will also be considered

Rules

- Teams may think of ideas and approaches as well as do research before the hackathon. However development of the system may not be done beforehand.
- Panel must not be damaged or disassembled
- No equipment interacting/interfering with panel electronics

Provided Equipment

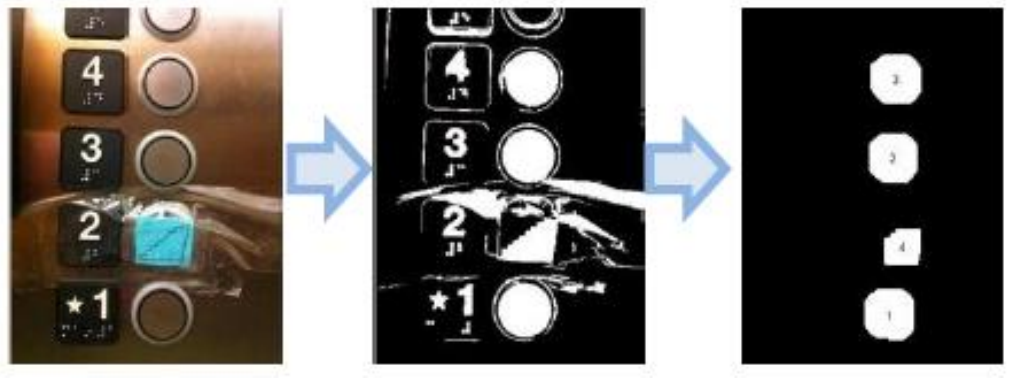
- USB camera
- Raspberry Pi 3B+
- Light sensors and limit switches

If there are any additional sensors that you think you could use to make a better solution, please let us know ASAP and we will see what we can do to help

Existing Approaches: IMAGE PROCESSING

Key steps

- Feature extraction (e.g. canny, zerocross, log, sobel edge detection)
- Separate objects from background and detect connected components (Binarization → Dilation → Erosion)
- Noise elimination and labelling (Blob)

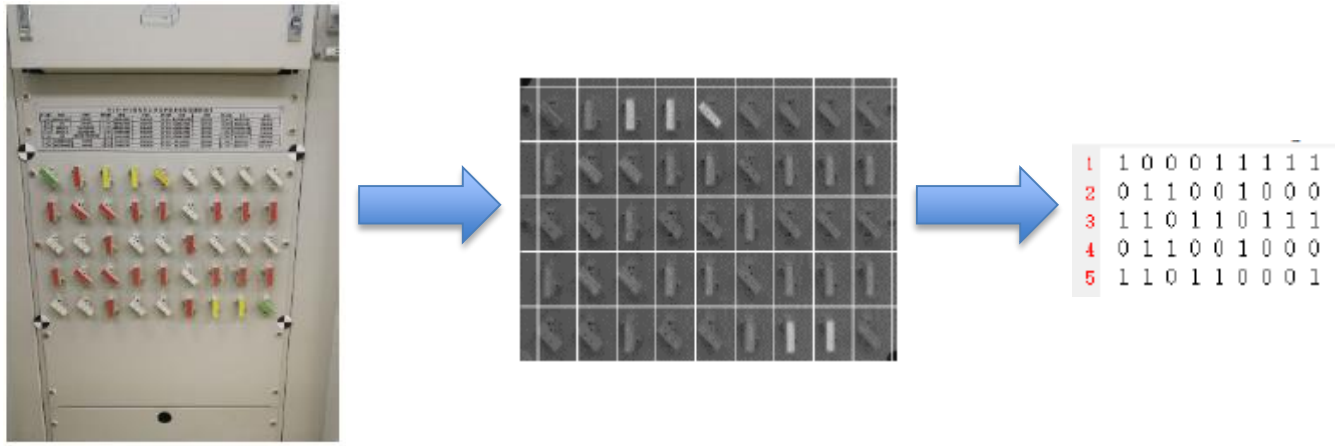


[1] Elevator's External Button Recognition and Detection for Vision-based System, F. Zakaria et al., EECSI 2014.

Existing Approaches: MACHINE LEARNING

Key steps

- Inverse perspective transformation (rectification)
- Region of interest and switches identification (segmentation)
- Closed and disconnected switches → support vector machine
- 795 samples



[3] Status recognition method for protecting panel of substation equipment with a mobile phone image, X. Zhou, SPIE v11069, 2019.

Existing Approaches: DEEP LEARNING

Key steps

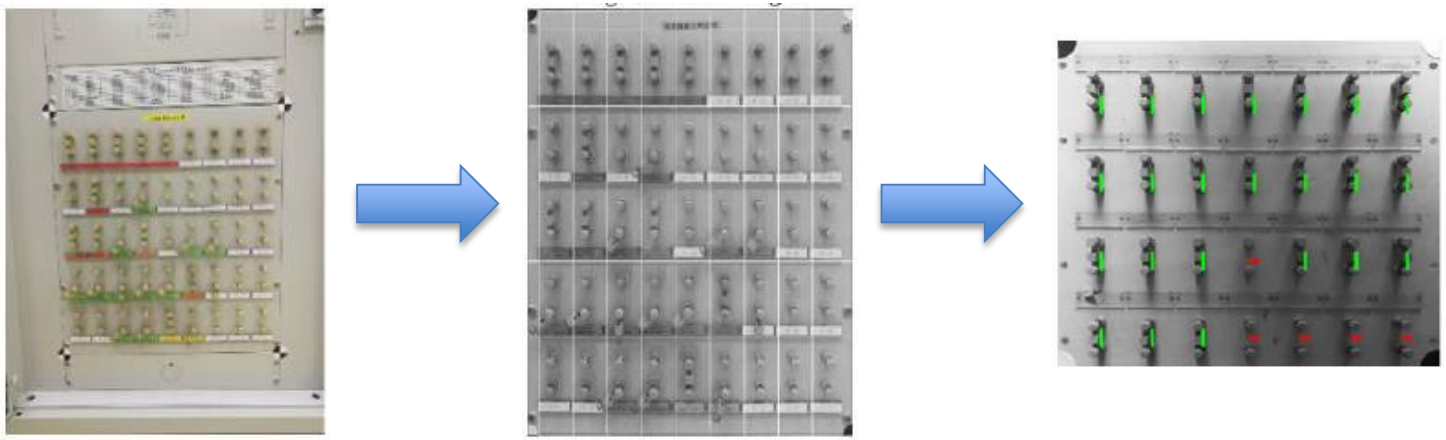
- Different angles and distances
- 800 elevator panel images from videos
- 10,000 sample buttons including diff styles, sizes, tilt angles and blur degrees
- Greyscale + noise removal + filtering processes

[2] Autonomous Elevator Button Recognition System Based on CNN, Z. Don et al., IEEE ICRB 2017.

Existing Approaches: DEEP LEARNING

Key steps

- Inverse perspective transformation (rectification)
- Region of interest and switches identification (segmentation)
- Closed and disconnected switches → CNN
- 1600 segmented samples



[4] State Recognition of Electric Control Cabinet Switches Based on CNNs, X. Mou et al., IEEE Image, Vision and Computing, 2018

Possible Approach: REAL-TIME OBJECT DETECTION

Elements Perspective

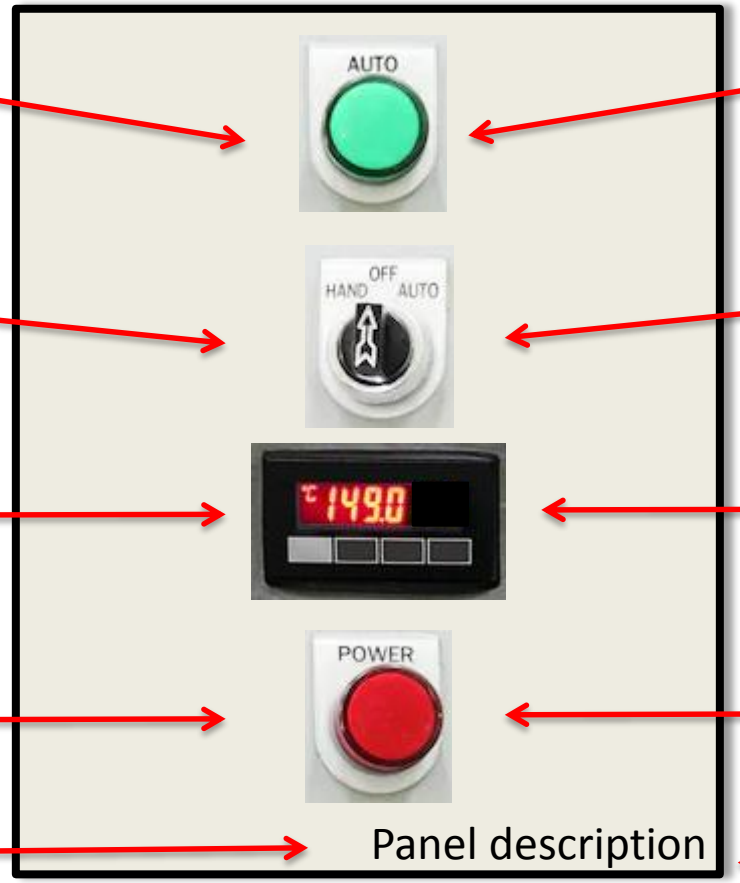
Green button sets panel on and off

Position button turns to manual, off and auto

Digital display with current operational value

Red button goes on and off in cycles

Label describes panel purpose



Object is lit or unlit

Object positions left, centre or right

Object content changes automatically

Object is lit and unlit in cycles

Object with fixed information

Objects Perspective

Possible Approach: REAL-TIME OBJECT DETECTION

Read panel status

gather training data

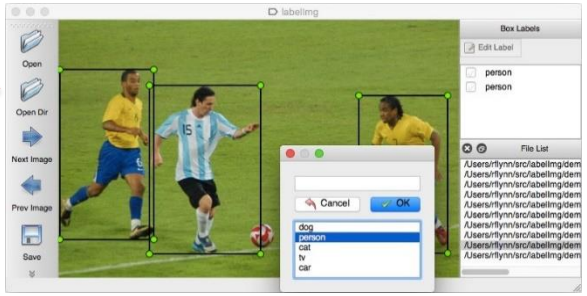
STEP 1

CAMERA: CAPTURES IMAGES

STEP 2

ANNOTATOR: ANNOTATES IMAGES

LabelImg



STEP 3

GPU: PRE-PROCESSING

STEP 4

GPU: TRAINS MODEL

train model

pre-trained models for out-of-the-box inference

STEP 5

CLIENT DEVICE: CAPTURES IMAGE

STEP 6

CLIENT DEVICE: PREDICTS IMAGE

predict new image

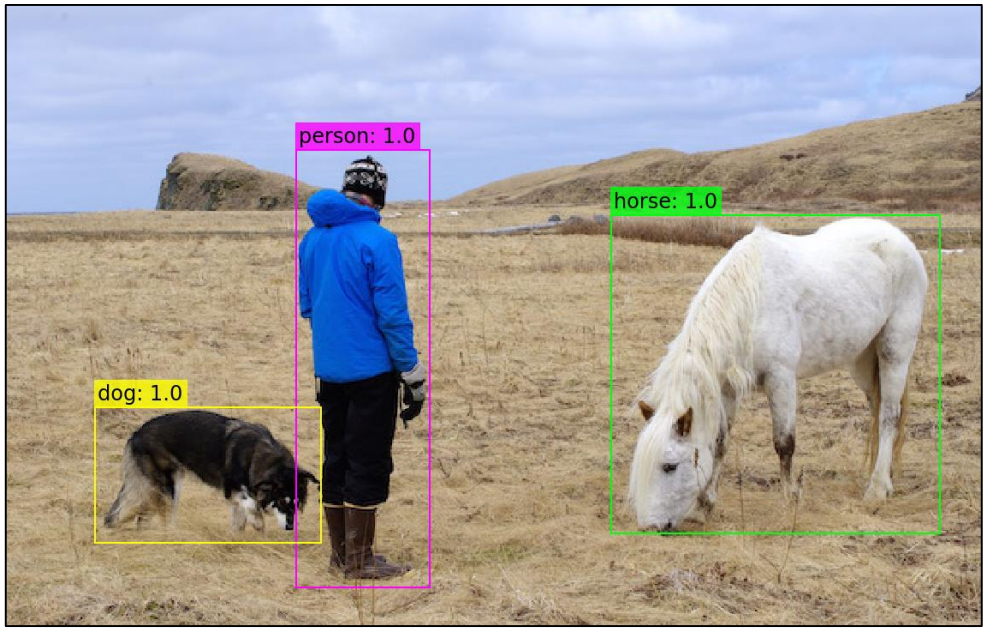
Re-read panel status

Capture status per control element

Possible Approach: REAL-TIME OBJECT DETECTION

Yolo

- You only look once – Liu et al., 2015
- https://pjreddie.com/darknet/yolo/



https://youtu.be/MPU2HistivI

Possible Approach: REAL-TIME OBJECT DETECTION

SSD (single shot multibox detector)

- https://heartbeat.fritz.ai/real-time-object-detection-on-raspberry-pi-using-opencv-dnn-98827255fa60
- https://github.com/weiliu89/caffe/tree/ssd
- https://link.springer.com/chapter/10.1007/978-3-319-46448-0_2
- https://ai.google/research/pubs/pub44872

Other options

https://nanonets.com/blog/how-to-easily-detect-objects-with-deep-learning-on-raspberry-pi/

Possible Approach: SENSORS AND SWITCHES

Magnetically attached sensors are also a possibility. For instance you could consider attaching to panel:

- Light sensors
- Proximity sensors
- Limit switches

Supported By

- **Pitch-In** aims to collaboratively identify and address barriers to the successful development, introduction and further exploitation of the Internet of Things, focussing on addressing barriers across five key areas: Cities, Energy, Health and Wellbeing, Managing the Introduction of IoT and Manufacturing

- **AND Technology Research** has over 38 years of experience helping solve the biggest engineering and technology challenges at all stages of the development journey: from idea conception, direction and strategy, through design and development, to launch readiness testing and post-launch lifecycle management.

- **GiroNEX Ltd** is a Cambridgeshire based technology company building state-of-the-art intelligent automated gravimetric weighing instruments for powder dispensing. As a spin-out from GB Innomech, Gironex is solely focussed on developing its dispensing technology for a range of environments and markets.

- **Warren Services** was founded in 1990 and provides high quality manufacture of components and mechanical / electrical sub assemblies to agreed schedules offering turnkey solutions in engineering and design.

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