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pucv.cl

Tool Tracking Dataset

Multi-modal / multi-class Time-Series Classification and Segmentation Dataset

Escuela de Ingeniería Informática

Valparaíso, 2025

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Agenda

- Materials
- Motivation
- System Design
- Hand-held tools
- Time-Series Dataset
- Summary

Materials

Data

- GitHub: https://github.com/crispchris/tool-tracking
- Data https://christofferloeffler.com/tooltracking/tool-tracking-data.zip

Papers

- Löffler et al.: *"Automated Quality Assurance for Hand-Held Tools via Embedded Classification and AutoML"*. In: ECML 2020. pdf demo presentation
- Redzepagic et al.: *"A Sense of Quality for Augmented Reality Assisted Process Guidance"*. In: ISMAR 2020. paper
- Mishra et al.: *"Recipes for Post-training Quantization of Deep Neural Networks"*. In: EMC^2 2020. paper
- Löffler et al.: *"Don't Get Me Wrong: How to Apply Deep Visual Interpretations to Time Series"*. Arxiv preprint, 2023. preprint

Project websites

- https://www.iis.fraunhofer.de/en/ff/lv/dataanalytics/anwproj/werkzeug.html
- https://www.iis.fraunhofer.de/en/ff/lv/dataanalytics/anwproj/ki4tools.html

Images: © Fraunhofer IIS

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Motivation

Quality Assurance in Assembly

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Tesla again shuts down Model 3 production line
Model 3 production halted

Automation knows limits

Human labor remains important

- flexible, literally handy with many kinds of tools

Meanwhile at BMW (Regensburg, Germany)

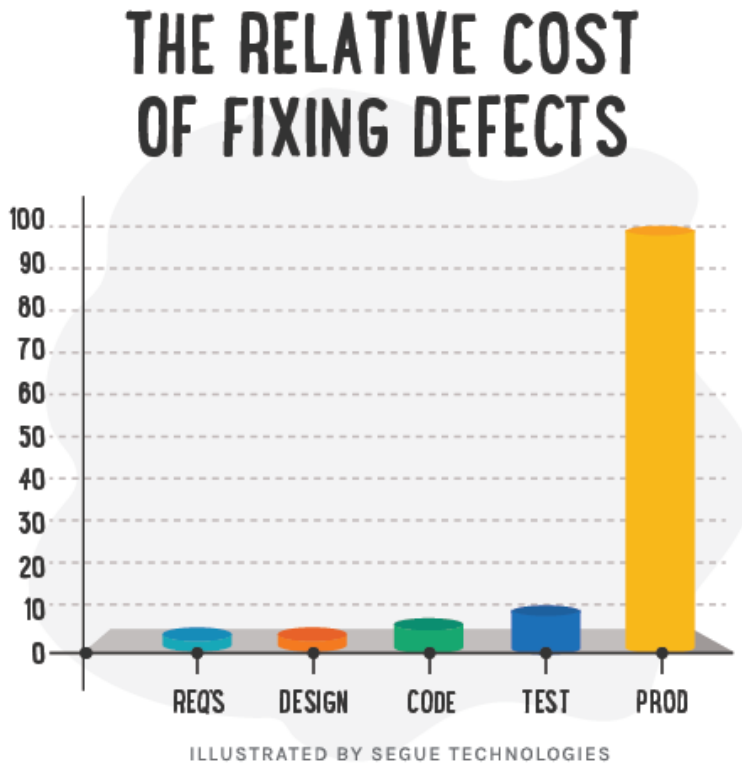
However, human labor is not automated

- gaps in quality assurance (QA)
  - long work shifts and distractions can lead to mistakes

Sometimes human workers make mistakes

It is worth it to detect mistakes early

- Cost of fixing mistakes relative to when they are discovered.



Problem analysis and how to assure quality

Problem Analysis

- Workers in assembly perform a manual and repetitive task
- Mistakes through lacking concentration or changing assembly steps (build-to-order, customized cars, ..)
- Work is harsh on the worker's body

Quality Assurance systems

- as post-production step for randomly sampled cars
- Expensive, heavy tools
- Optical camera systems are limited by design

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System Design

Requirements and Solutions

Requirements for next generation QA systems

Tools themselves must detect and monitor the work process

- Make tools intelligent and light weight
- Automate Quality Assurance

System's challenges

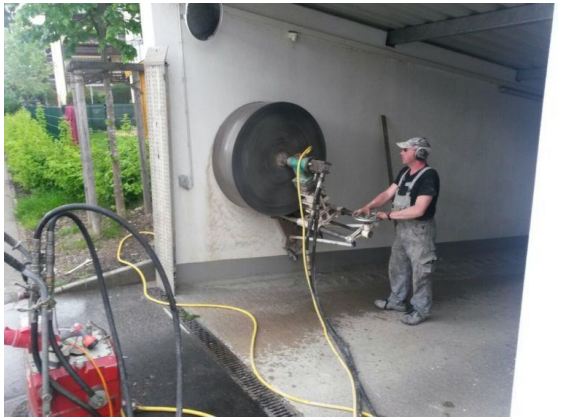
Challenges

1. Must work with many different hand-held tools to be financially viable as a product

System's challenges

Challenges

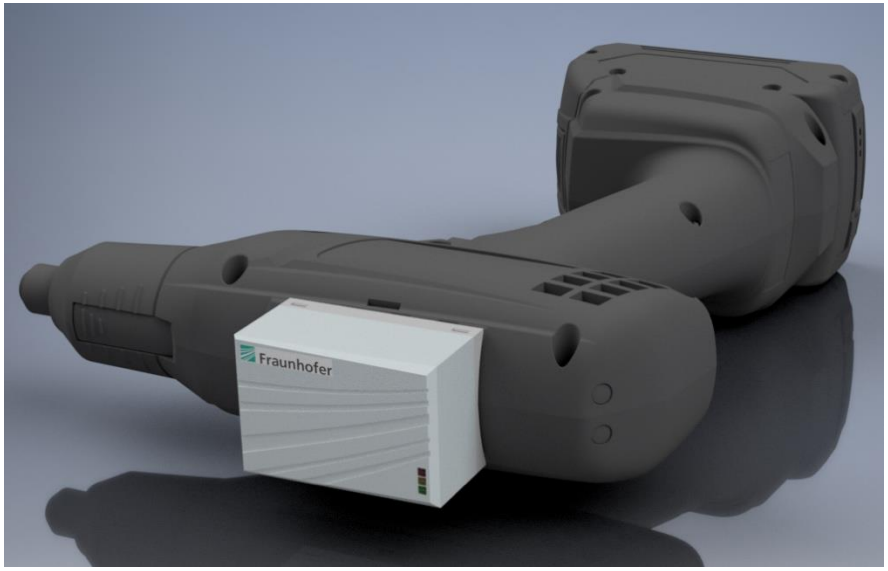
2. Must be easily applied to a wide variety of tasks, quickly and cheaply



Hardware description

Add Machine Learning to any hand-held tool

- Multi-modal sensors
- Analyze data on device
- Wireless data transfer to QA



Hardware description

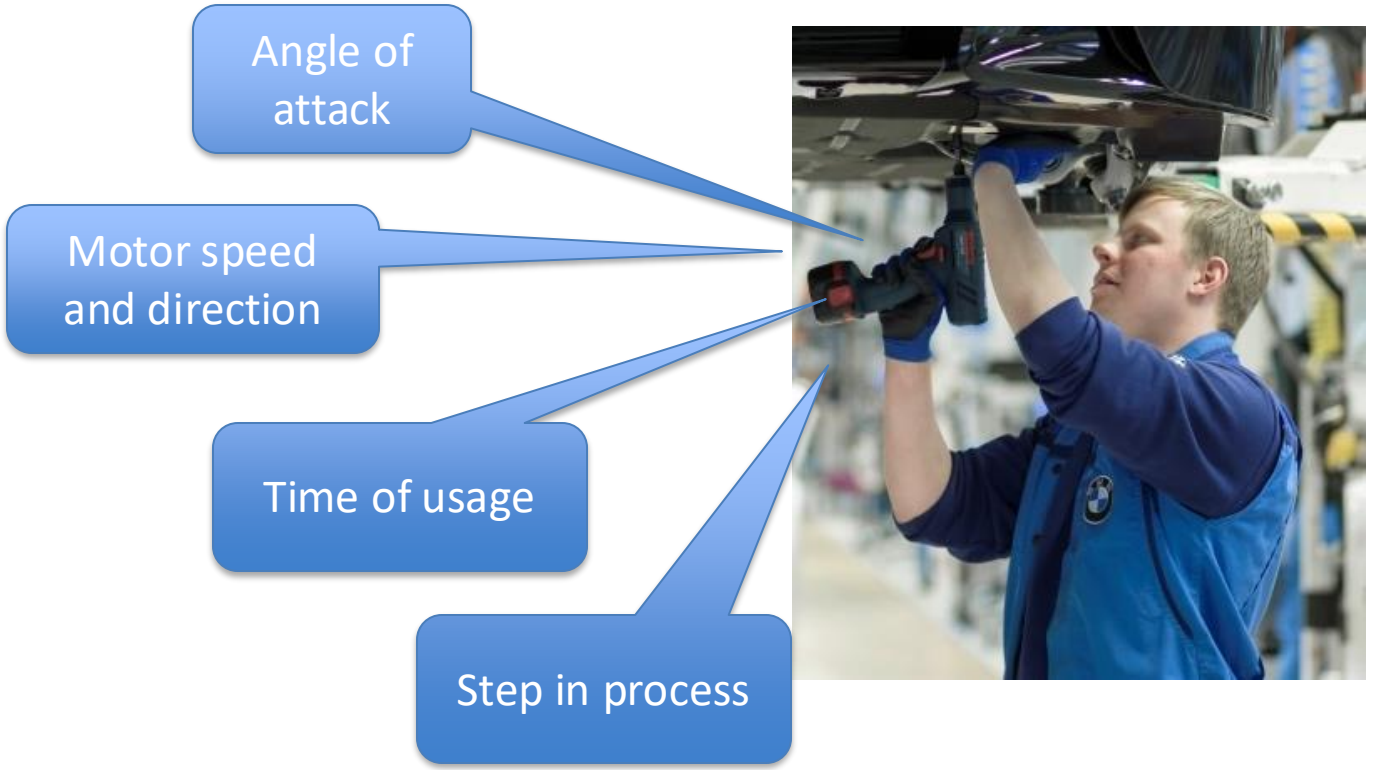
After-market add-on box

- 3D-printed socket, slide on hardware to fix to device

What do we need to measure?

Depends on how a hand-held tool is used!

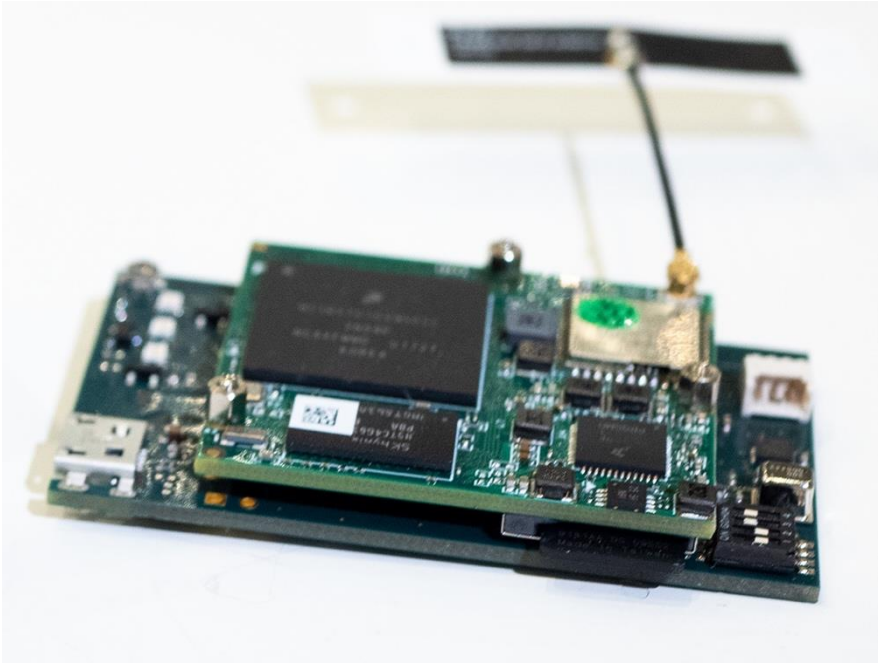
Example: Electric Screwdriver



A look inside

Sensor specifications

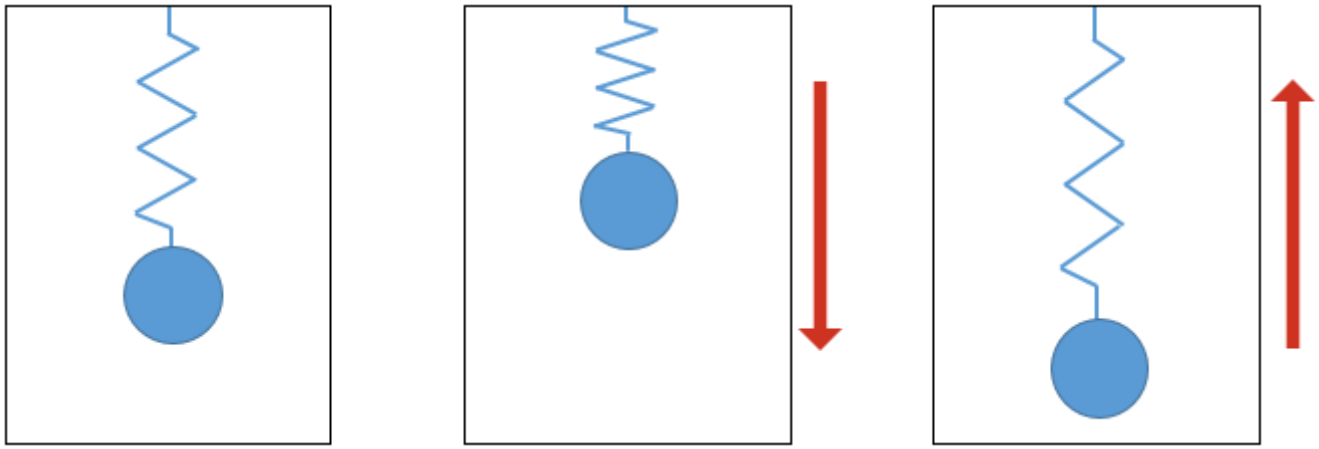
- 9-axis Inertial Measurement Unit (IMU)
- Microphone



Inertial Measurement Unit

Accelerometer

- 3-axis at 102.292 Hz
- Measures acceleration $\frac{m}{s^2}$
- Acceleration towards earth is "gravity" $9.81\frac{m}{s^2}$



Motion down compresses spring

Motion up decompresses spring

Source: https://bdavison.napier.ac.uk/iot/Notes/components/accelerometer/

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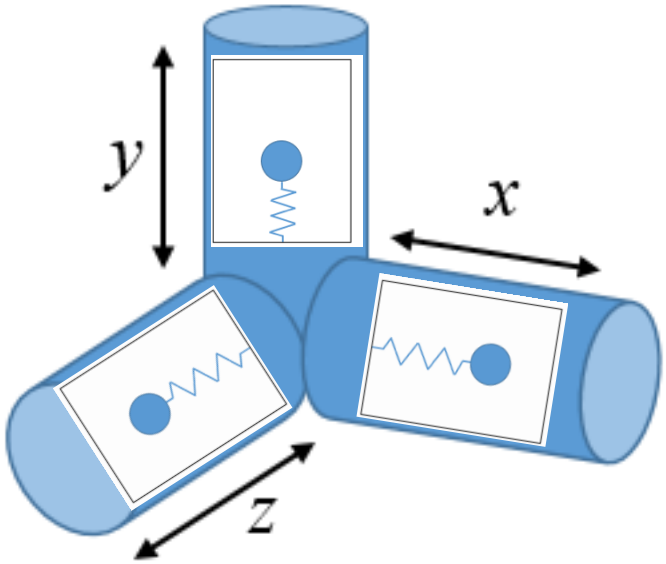
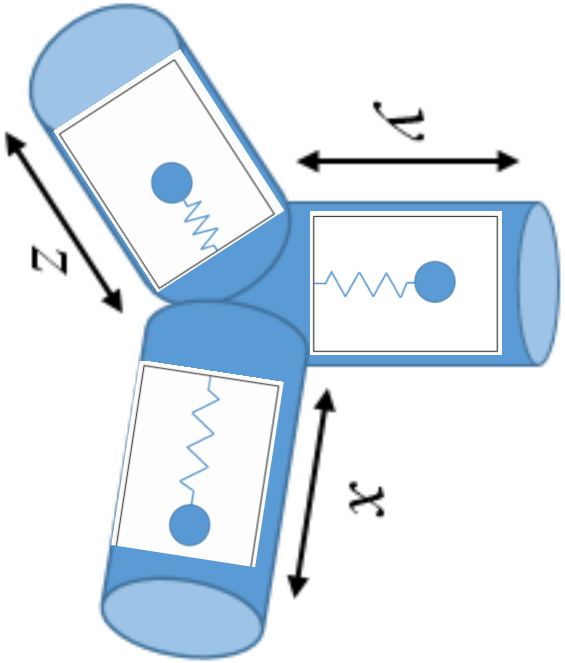
Accelerometer

- 3-axis: Why?





Source: https://bdavison.napier.ac.uk/iot/Notes/components/accelerometer/

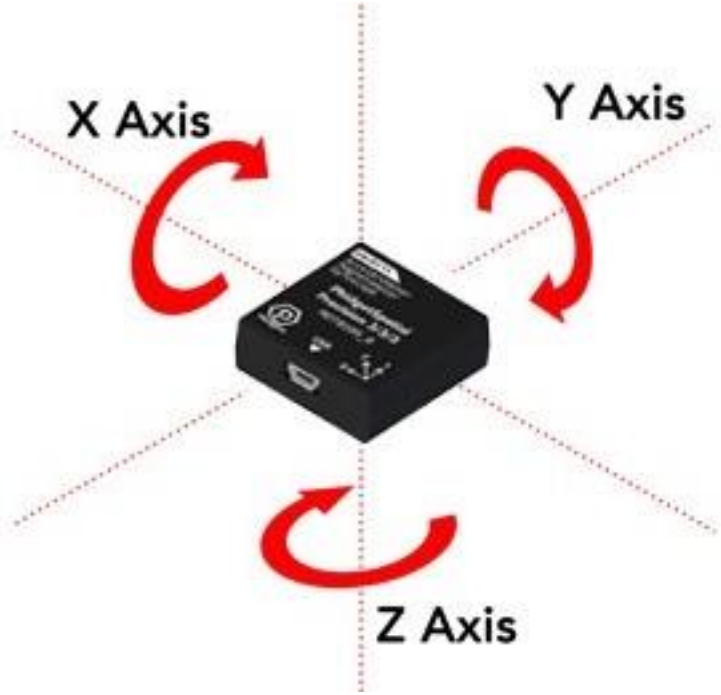
Inertial Measurement Unit

Gyroscope

- 3 axis at 102.292 Hz
- Measures rotation degrees $\frac{°}{s}$

Example:

- no motion, values 0.0
- Rotation around axis



Source: https://www.phidgets.com/docs/Gyroscope_Guide

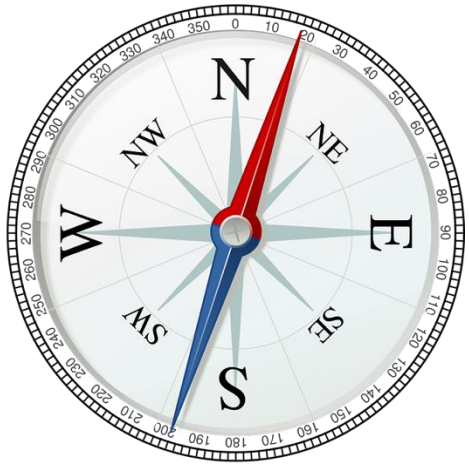
Inertial Measurement Unit

Magnetic Field sensor

- 3-axis compass at 154.646 Hz
- Measures strength of magnetic field in Gauss
- Axis that points north should have higher reading

Example:

- Earth magnetic field: 0.25 to 0.65 G
- Toaster: 2-10 mG
- Power Transmission Line: 10-200 mG
- Engine: 4000-6000 G

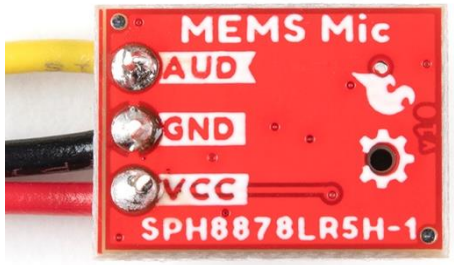


Source: https://www.arpansa.gov.au/understanding-radiation/radiation-sources/more-radiation-sources/measuring-magnetic-fields

Microphone

Microphone
- Records mono sounds at 44 kHz

Examples:
- Engine sounds
- Hammering
- Anything in the background



Proposed system

9-axis Inertial Measurement Unit (IMU)

- Movements and accelerations
  - Vibrations, motion, hits, ..
- Rotations
  - Interpret motion better
- Magnetic or electro-magnetic fields
  - Absolute orientation, electric motors, ..

Source: https://www.youtube.com/watch?v=i5Z8JOdyCpk

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Hand-held Tools

The tools and their characteristics

Hand-held tools

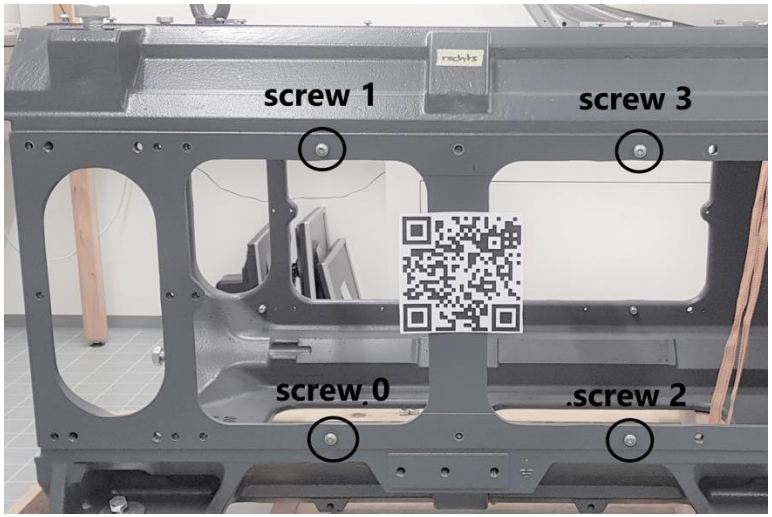
Tools recorded in the dataset

- Electric Screwdriver
- Pneumatic Rivet Gun
- Pneumatic Screwdriver

Hand-held tools

Electric Screwdriver

- Has an electric engine
  - Induces strong magnetic field → mag
  - Smooth operation, low vibration
- Tighten screws until tight enough, stops automatically
  - Strong twisting rotation measurable → gyr



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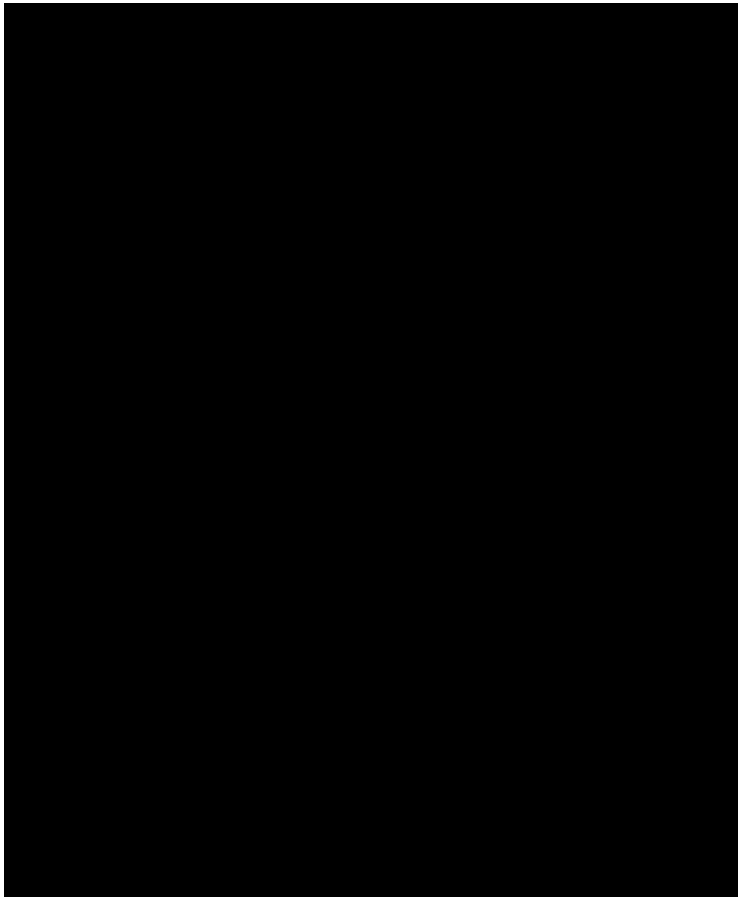
Demonstration

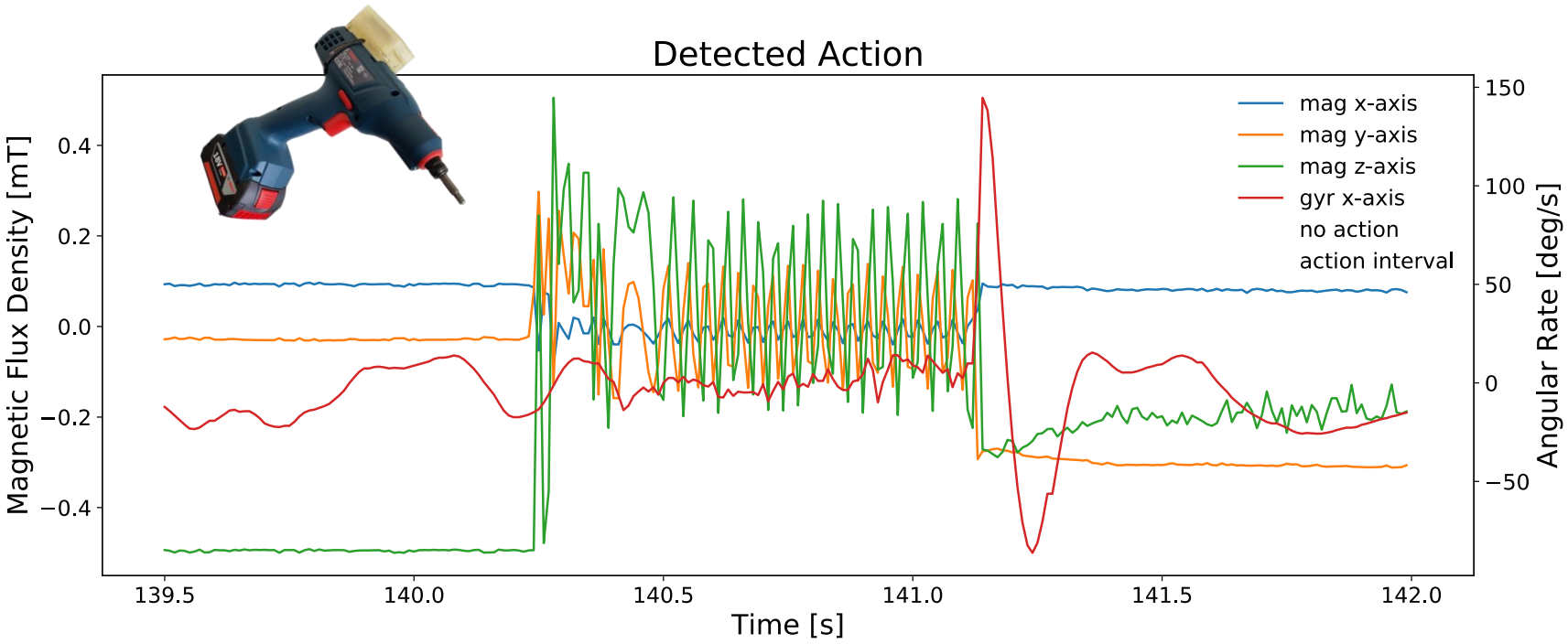
- Notice the motion
- End of screwing: harsh stop



Hand-held tools

Typical sensor reading

- Magnetic field very strong
- Gyroscope shows twisting rotation at the end



Hand-held tools

Pneumatic Screwdriver

- Similar to electric variant
- Made for heavy duty work

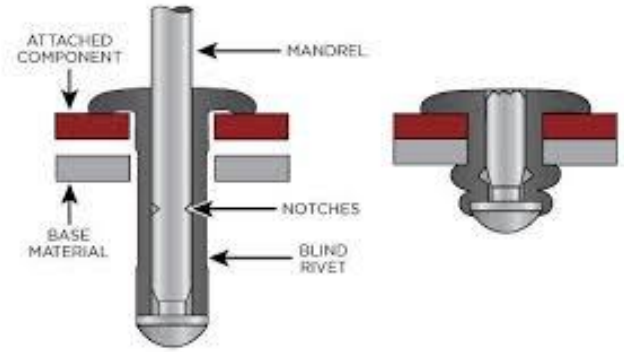
Works with pressurized air

- No induced electromagnetism → mag is useless
- Longer, very loud action with specific acceleration profile
  - Mic, acc, gyr
- No hard deceleration when done
  - Loud, continuous clacking noise instead

Hand-held tools

Pneumatic Rivet Gun

- Works with pressurized air
  - No induced electromagnetism → mag is useless
- Short, loud action with specific acceleration profile
  - Mic, acc, gyr



Sources: youtube and https://www.huyett.com/blog/what-is-a-blind-rivet

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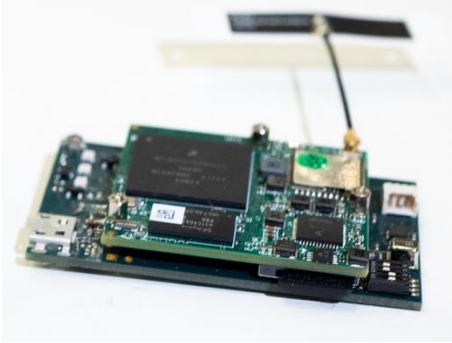
Time-Series Dataset

multimodality, multiclass,
anomalies & out-of-distribution,
classification or segmentation, ...

Terminology



Multimodality:
- 4 types of sensors
- **Orthogonal information**

Multiclass:
- More than 2 classes per tool
- Multilabel: **hierarchical labels** can be constructed from data

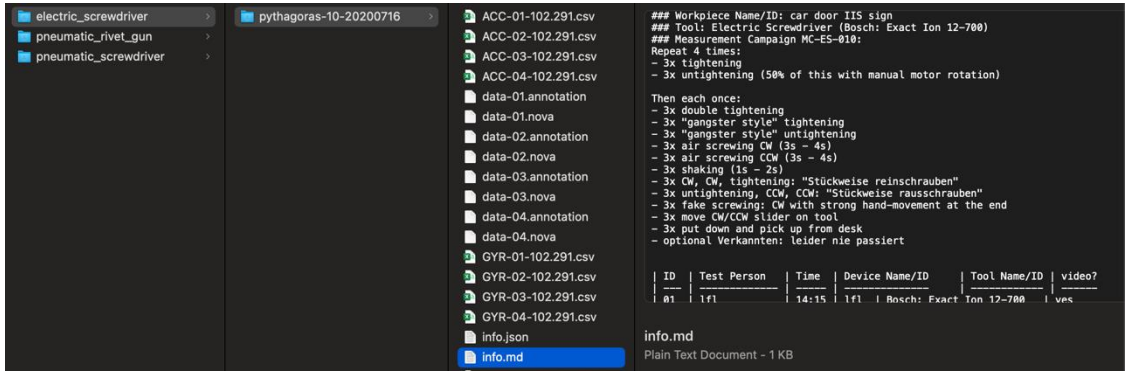
Difficulty and Realism
- **Anomalies**: recordings of errors on purpose
- **Out-of-distribution**: test your models against specific hold-out classes unseen during training, e.g., erroneous anomalies

Tasks
- **Classification** of windows or **segmentation** of data stream

Hand-held tools: Actions

Electric Screwdriver's actions
- Tighten, Untighten

Special actions (Optional anomalies)
- *Screwing (Clockwise, Counter Clockwise)*
- *Double tightening (already tightened)*
- *Held sideways ("gangster style")*
- *Screwing but in Air*
- *Shaking the tool*
- *Picking it up, setting it down*
- *Faking the screwing by rotation device head by hand*
- *Moving the settings-slider on the tool*



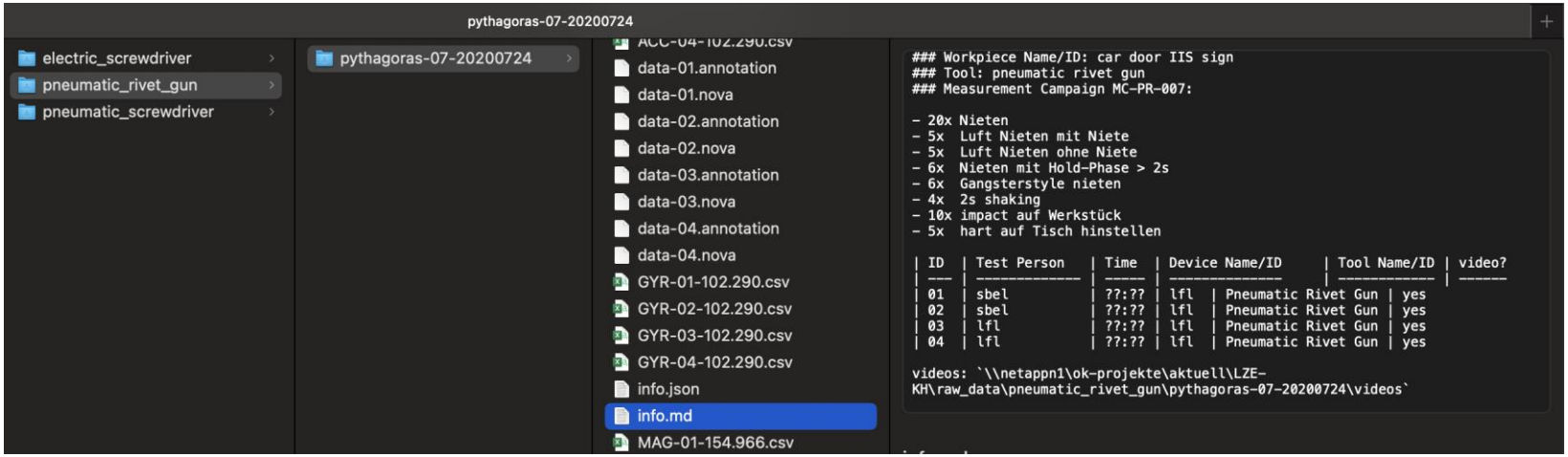
Hand-held tools: Actions

Pneumatic Rivet Gun's actions

- Rivetting

Special actions (Optional anomalies)

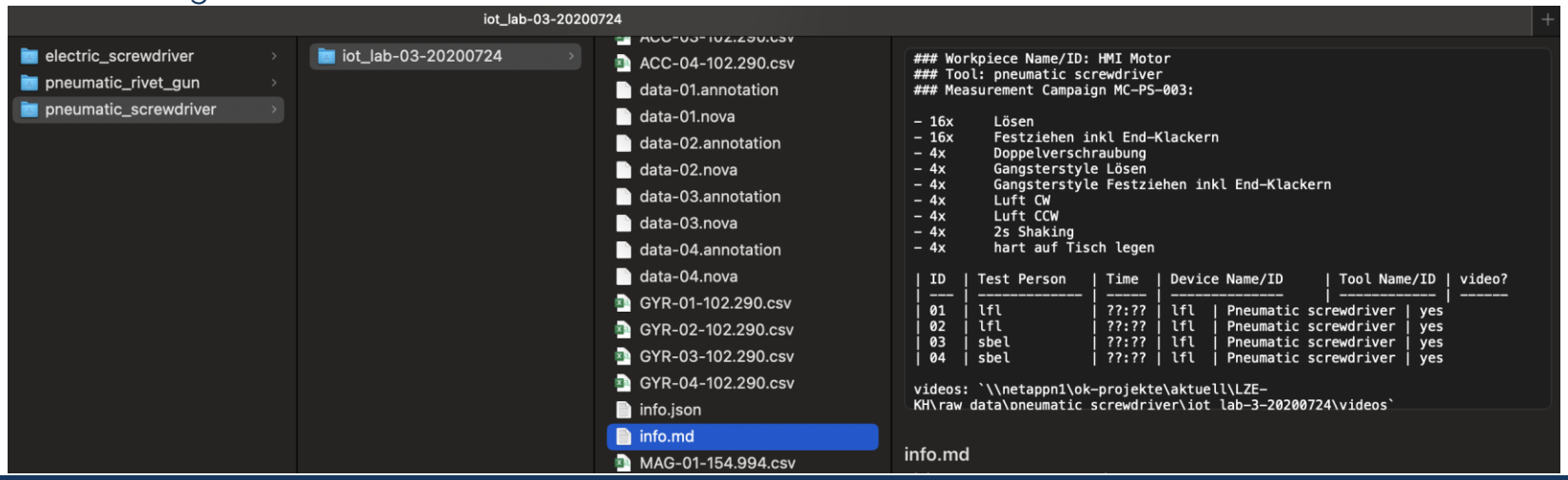
- Rivetting in the air: with/without rivet inserted before
- Rivetting done with waiting before moving tool again
- Shaking the riveter
- Held sideways
- Hitting the work piece
- Putting down hard on table



Hand-held tools: Actions

Pneumatic Screwdriver's actions
- Tightening
- Untightening

Special actions (Optional anomalies)
- Double tightening
- Tool-use in air without screws (CW/CCW)
- Shaking
- Held sideways
- Putting down on table



Dataset

Recording of **large dataset**

- 3 tools:
  - Electric Screwdriver
  - Pneumatic Rivet Gun
  - Pneumatic Screwdriver

Repeated **recordings**

- 2 different workers (lfl, sbel)
- 2 recording runs per person

Structured recordings

- exact list what to do with each tool, simplifies annotation
- Repetitions of actions within each run

```
### Workpiece Name/ID: car door IIS sign
### Tool: Electric Screwdriver (Bosch: Exact Ion 12-700)
### Measurement Campaign MC-ES-010:
Repeat 4 times:
- 3x tightening
- 3x untightening (50% of this with manual motor rotation)

Then each once:
- 3x double tightening
- 3x "gangster style" tightening
- 3x "gangster style" untightening
- 3x air screwing CW (3s - 4s)
- 3x air screwing CCW (3s - 4s)
- 3x shaking (1s - 2s)
- 3x CW, CW, tightening: "Stückweise reinschrauben"
- 3x untightening, CCW, CCW: "Stückweise rausschrauben"
- 3x fake screwing: CW with strong hand-movement at the end
- 3x move CW/CW slider on tool
- 3x put down and pick up from desk
- optional Verkannten: leider nie passiert


| ID  | Test Person  | Time  | Device Name/ID      | Tool Name
| --- | ------------ | ----- | ------------------- | ----------
| 01  | lfl          | 14:15 | lfl  | Bosch: Exact Ion 12-700
| 02  | lfl          | 14:45 | lfl  | Bosch: Exact Ion 12-700
| 03  | sbel         | 15:?? | lfl  | Bosch: Exact Ion 12-700
| 04  | sbel         | 15:?? | lfl  | Bosch: Exact Ion 12-700
```

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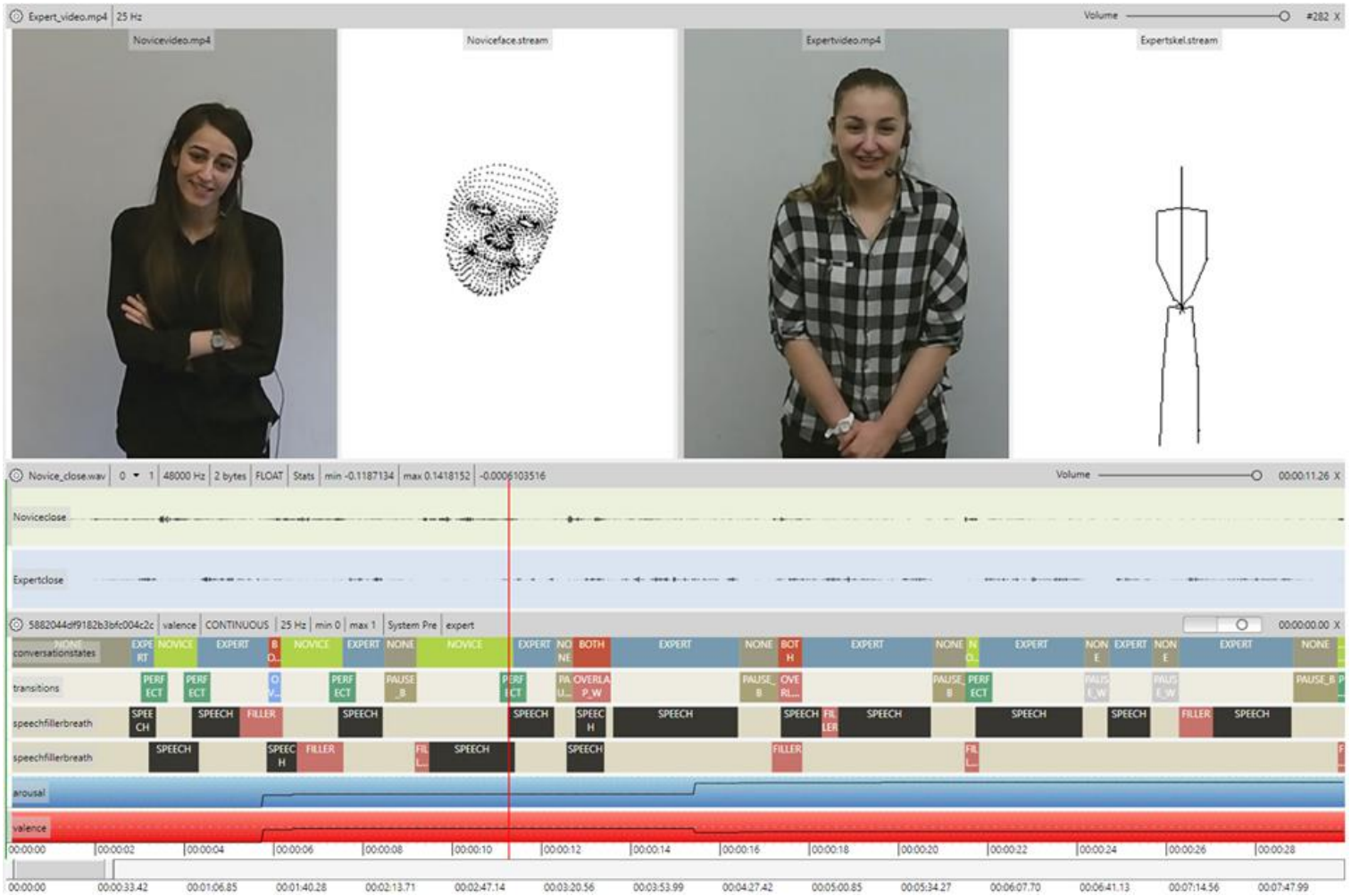
Annotations tool: Nova



Source: https://github.com/hcmlab/nova

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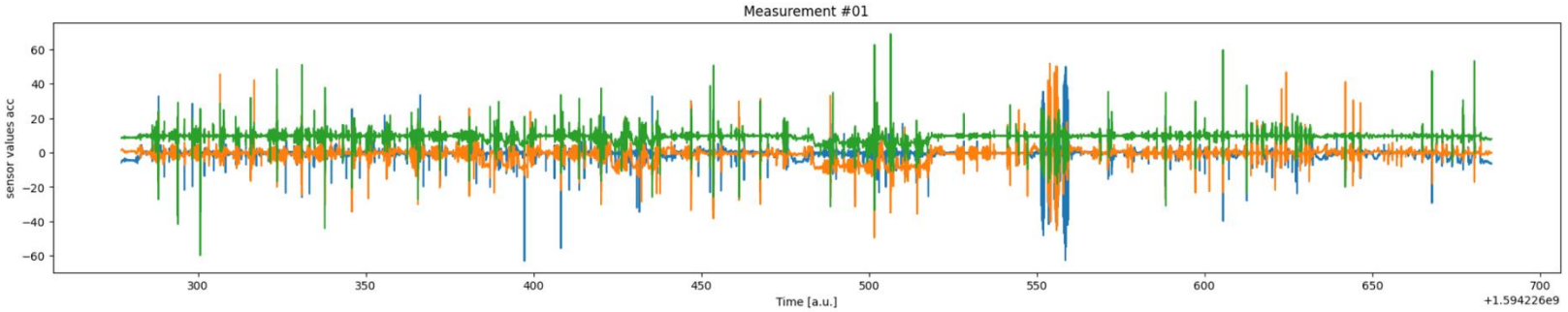
Annotations

Dense Labels

- each sample from each sensor has class annotation

→ You can cut windows from the data (overlapping, tumbling, ..)
→ You can continuously classify the “data stream”
→ Implement anomaly/out-of-distribution detection
→ You can implement time-series segmentation (sample-level prediction)



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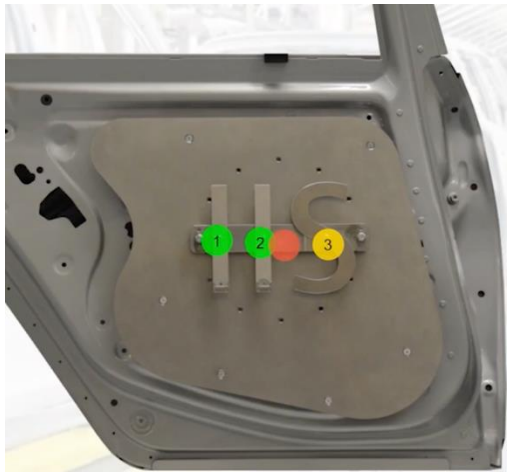
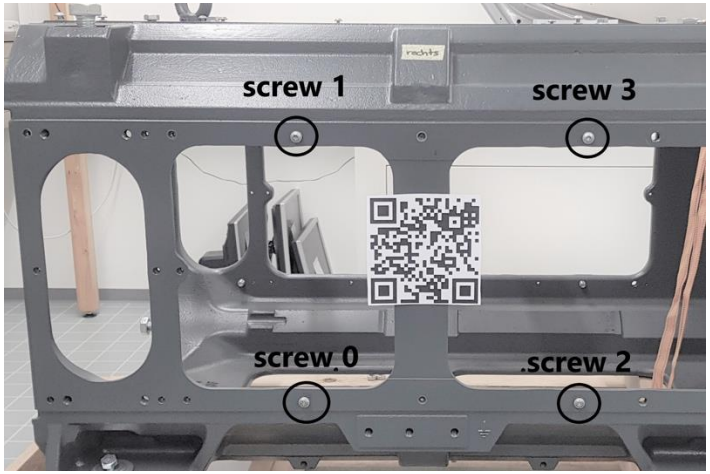
Different work pieces:
BMW doors or engine block.

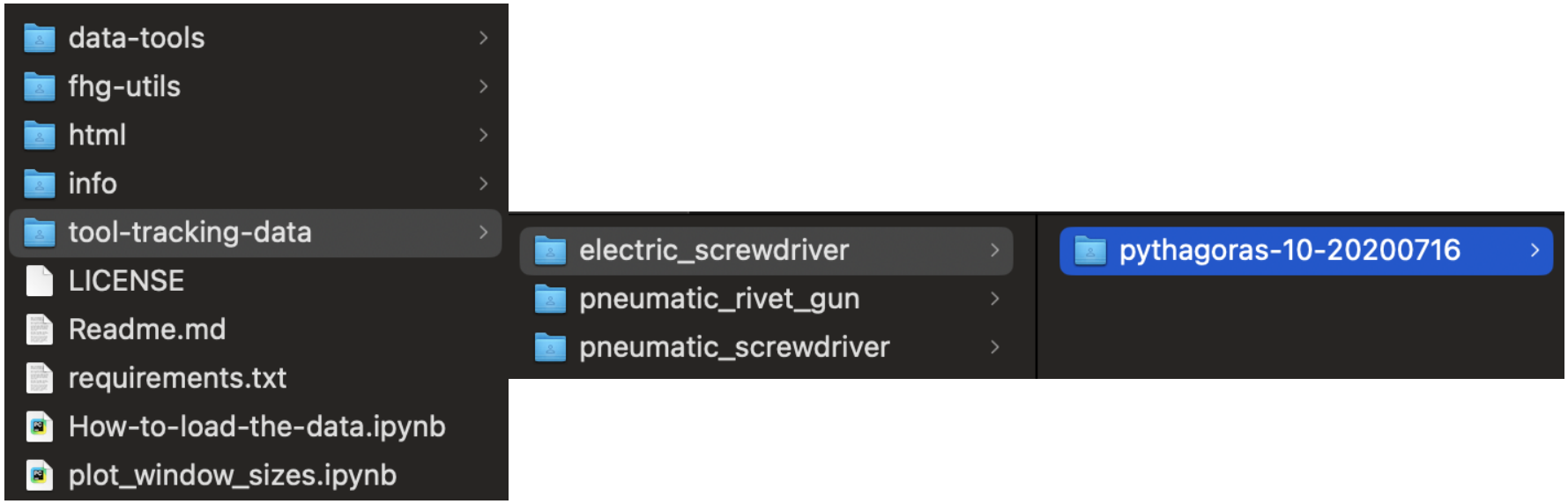




Example data: Electric Screwdriver

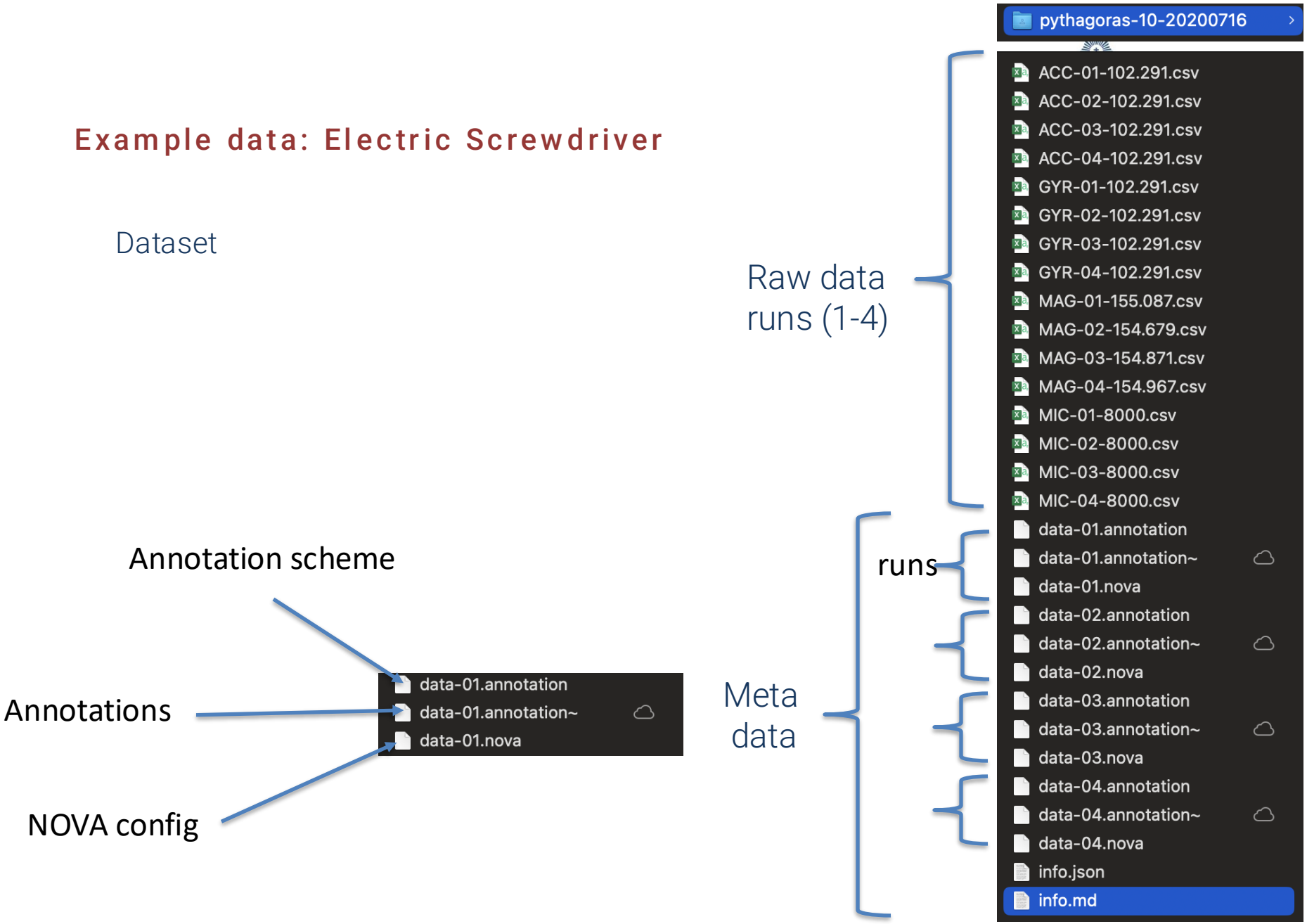
Folder structure

Data:	`tool-tracking-data`
Data Loader:	`data-tools, fhg-utils`
Documentation:	`html`
Demonstrations:	`How-to-load-the-data.ipynb`
	`plot_window_sizes.ipynb`



Example data: Electric Screwdriver

Dataset



Example data: Electric Screwdriver

Raw data:
ACC: Accelerometer
01: run ID 01 (here, Ifl recorded this run)
102.291 sampling rate in Hz

ACC-01-102.291.csv

The file size (3.17 MB) exceeds the configured limit (2.56 MB). Code insight features are not available.

```
time [s];acceleration x-axis [m/s^2];acceleration y-axis [m/s^2];acceleration z-axis [m/s^2]
1594226277.18598;-5.877378;1.322051;8.612491
1594226277.1957562;-5.819896530061611;1.2933097562023466;8.59332943464816
1594226277.2055323;-5.75962317633312;1.2423090772136065;8.570147747798787
1594226277.2153087;-5.678890970294857;1.2174626285881522;8.56938
1594226277.2250845;-5.483503755701358;1.2118799999999998;8.418252449596332
1594226277.2348607;-5.425912645010244;1.2384668129938543;8.358493313432836
1594226277.2446368;-5.307209670958254;1.2981775936644415;8.333272023079536
1594226277.2544131;-5.182684541288656;1.2792715650424349;8.30552778197249
1594226277.264189;-5.058761732186216;1.4256730596750091;8.26228634936496
1594226277.2739651;-4.918982586152233;1.430202637026559;8.218632913957515
```

Example data: Electric Screwdriver

Annotation scheme and range-based annotations

"Undefined" (idle) *id* = 8

Invalid (trash) *id* = -1

$t_{start}; t_{stop}; id; 1$

data-01.annotation

```
<?xml version="1.0" ?>
<annotation ssi-v="3">
    <info ftype="ASCII" size="157" />
    <meta annotator="" role=""/>
    <scheme name="electric_screwdriver" type="DISCRETE"  color="#FFFFFFFF">
        <item name="undefined" id="0" color="#FFD3D3D3" />
        <item name="tightening" id="1" color="#FF1F77B4" />
        <item name="untightening" id="2" color="#FFFF7F0E" />
        <item name="motor_activity_cw" id="3" color="#FF2CA02C" />
        <item name="motor_activity_ccw" id="4" color="#FFD62728" />
        <item name="manual_motor_rotation" id="5" color="#FF9467BD" />
        <item name="shaking" id="6" color="#FF8C564B" />
        <item name="tightening_double" id="7" color="#FFE377C2" />
    </scheme>
</annotation>
```

data-01.annotation~

```
0;8.76;0;1
8.76;11.144771;1;1
11.144771;14.56;0;1
14.56;16.88;1;1
16.88;20.920887;0;1
20.92;23.56;1;1
23.56;29.36;0;1
29.36;30.52;2;1
30.52;34.020882;0;1
34.020882;35.08;2;1
35.08;38.48;0;1
38.48;39.6;2;1
39.6;43.72;0;1
43.72;46.44;1;1
46.44;51.36;0;1
51.36;53.88;1;1
53.88;58.08;0;1
58.08;60.72;1;1
60.72;68.64;0;1
68.64;69.76;2;1
```

How to load the data

1. How to load the Data

Software setup:

```
conda create --name tool-tracking_env python=3.12
conda activate tool-tracking_env
pip install -r requirements.txt
jupyter notebook
```

1.2. 1. Load Data with `data-tools`

First we have to connect to our downloaded data using the main class:

[1]:
```
from pathlib import Path
from datatools.fixture import setup_dummy_data
# test_tool
# source = setup_dummy_data(5)

# put data into this source folder
source = "./tool-tracking-data/"
```

[5]:
```
from datatools import MeasurementDataReader, Measurement, MeasurementSeries, Action
mdr = MeasurementDataReader(source=source)
```

How to load the data

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1.2.1. 1.1 Create a Query to load *Measurements* or *Actions*

Using the `mdr` object we can create a `Query` object to formulate a query to the data source.

[6]:
```
q = mdr.query(query_type=Measurement)
```

Depending on the use case you can query for *Measurements* which represents a temporal contiguous time series with inhomogeneous labels or *Actions* which are parts of *Measurements* but have the same label throughout their time range:

```
from datatools import Action
q = mdr.query(query_type=Action)
```

1.2.2. 1.2 Narrow a Query to load *Measurements* of interest

[7]:
```
from datatools import Tool, Config, MeasurementSeries, Measurement, DataTypes, Action
from datatools import ACC, GYR, MAG, MIC, POS, VEL

mytool = "electric_screwdriver"
#mytool = "pneumatic_screwdriver"
#mytool = "pneumatic_rivet_gun"
#mytool = "test_tool"

data_dict = q.filter_by(Tool == mytool, DataTypes == ACC).get()
```

How to load the data: Load Measurement

1.2.2. 1.2 Narrow a Query to load *Measurements* of interest

[7]:
```
from datatools import Tool, Config, MeasurementSeries, Measurement, DataTypes, Action
from datatools import ACC, GYR, MAG, MIC, POS, VEL

mytool = "electric_screwdriver"
#mytool = "pneumatic_screwdriver"
#mytool = "pneumatic_rivet_gun"
#mytool = "test_tool"

data_dict = q.filter_by(Tool == mytool, DataTypes == ACC).get()
```

```
[INFO] Preparing data from:
  tool-tracking-data/electric_screwdriver/pythagoras-10-20200716
  tool-tracking-data/electric_screwdriver/pythagoras-10-20200716
  tool-tracking-data/electric_screwdriver/pythagoras-10-20200716
  tool-tracking-data/electric_screwdriver/pythagoras-10-20200716
[INFO] Read annotation: 100%|████████████████████████████████████████████████████
████████████████| 16/16 [00:00<00:00, 176.74it/s, file=data-03.annotation]
[WARN] The mean sampling rate from the filename (tool-tracking-data/electric_screwdrive
r/pythagoras-10-20200716/ACC-02-102.291.csv) and from the timestamps differ by 0.001Hz

[WARN] The mean sampling rate from the filename (tool-tracking-data/electric_screwdrive
r/pythagoras-10-20200716/ACC-04-102.291.csv) and from the timestamps differ by 0.001Hz

[WARN] The mean sampling rate from the filename (tool-tracking-data/electric_screwdrive
r/pythagoras-10-20200716/ACC-01-102.291.csv) and from the timestamps differ by 0.001Hz

[WARN] The mean sampling rate from the filename (tool-tracking-data/electric_screwdrive
r/pythagoras-10-20200716/ACC-03-102.291.csv) and from the timestamps differ by 0.001Hz

[INFO] Finished with 4 measurement(s).
```

How to load the data: Load Measurement

1.2.2. 1.2 Narrow a Query to load *Measurements* of interest

[7]:
```
from datatools import Tool, Config, MeasurementSeries, Measurement, DataTypes, Action
from datatools import ACC, GYR, MAG, MIC, POS, VEL

mytool = "electric_screwdriver"
#mytool = "pneumatic_screwdriver"
#mytool = "pneumatic_rivet_gun"
#mytool = "test_tool"

data_dict = q.filter_by(Tool == mytool, DataTypes == ACC).get()
```

...

[8]:
```
data_dict.keys()  # we have loaded five measurements
```

[8]:
```
dict_keys(['02', '04', '01', '03'])
```

[6]:
```
data_bunch = data_dict["01"] # data bunch for measurement with measurement id "01"
type(data_bunch)
```

[6]:
```
datatools.data.DataBunch
```

How to load the data: Load Measurement

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1.2.3. 1.3 Interaction with the `DataBunch` class

A DataBunch object is a dictionary-like object that exposes its keys as attributes. Access the data with `data_bunch.acc` or `data_bunch['audio']`. You can inspect which data is contained with:

[7]:
```
data_bunch.data_keys()
```

[7]:
```
['acc']
```

[8]:
```
data_bunch.acc.features
```

[8]:
```
['acceleration x-axis [m/s^2]',
 'acceleration y-axis [m/s^2]',
 'acceleration z-axis [m/s^2]']
```

[9]:
```
# matrix with raw sensor data with time column
Xt = data_bunch.acc.ts # numpy array

# matrix with raw sensor data (without time column)
X = data_bunch.acc.X  # numpy array

# target vector
y = data_bunch.acc.y  # numpy array
```

[10]:
```
print("shape of Xt: ", Xt.shape)
print("shape of X: ", X.shape)
print("shape of y: ", y.shape)
```

```
shape of Xt:  (41775, 4)
shape of X:  (41775, 3)
shape of y:  (41775,)
```

Alternative: Load ACTIONS

1.2.2. 1.2 Narrow a Query to load *Measurements* of interest

[7]:
```
from datatools import Tool, Config, MeasurementSeries, Measurement, DataTypes, Action
from datatools import ACC, GYR, MAG, MIC, POS, VEL

mytool = "electric_screwdriver"
#mytool = "pneumatic_screwdriver"
#mytool = "pneumatic_rivet_gun"
#mytool = "test_tool"

data_dict = q.filter_by(Tool == mytool, DataTypes == ACC).get()
```

1.2.4. 1.4 Narrow a Query to load *Actions* of interest

```
data_dict = mdr.query(query_type=Action).filter_by(Action == "tightening",
                                                   Tool == mytool).get()
```

```
[INFO] Read annotation: 100%|████████████████████████████████████████████████████████████| 16/16 [00:01<00:00, 10.90it/s, file=data-03.annotation]
[INFO] Finished with 79 action(s).
```

[12]:
```
data_dict.keys()  # the data is now grouped by actions
```

[12]:
```
dict_keys(['tightening'])
```

[13]:
```
data_bunches = data_dict["tightening"]
print(f"{type(data_bunches)} of {type(data_bunches[0])}")
```

```
<class 'list'> of <class 'datatools.data.DataBunch'>
```

Create windowed Time-Series: seglearn

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dmbee.github.io/seglearn/

1.3. 2. Create windowed Time-Series

[14]:
```
import numpy as np
from seglearn.base import TS_Data
from seglearn.pipe import Pype
from fhgutils import Segment, contextual_recarray_dtype, filter_ts_data
from datatools import to_ts_data
```

> Note: `to_ts_data` can deal with the output when querying *Measurements* as well as *Actions*

Have a look on the seglearn user guide to understand the data representation with `Xt` and `Xc`.

[15]:
```
window_length=0.4 # unit in s
overlap = 0.5 # unit in percent

# cl
data_
Xt, )

X = 
pipe
    (


])

X_trans, y_trans = pipe.fit_transform(X, y)
```

[34]:
```
print("[INFO] segmented data")
print(len(X_trans))
for i in range(0,4):
    print(X_trans[i].shape, y_trans[i].shape)
```

```
[INFO] segmented data
29060
[41] (41,)
[41] (41,)
[62] (62,)
[3200] (3200,)
```

Filter multimodal data for sensor modalities

Important: discard the TIMESTAMPS ☺

1.3.1. 2.1 Filter windowed Data

[35]:
```
print("[INFO] extract segmented ACC data")
Xt_acc, Xc_acc, y_acc = filter_ts_data(X_trans, y_trans, filt={'desc': ['acc']})

print("[INFO] extract segmented GYR data")
Xt_gyr, Xc_gyr, y_gyr = filter_ts_data(X_trans, y_trans, filt={'desc': ['gyr']})
```

```
[INFO] extract segmented ACC data
[INFO] extract segmented GYR data
```

[36]:
```
print("[INFO] shape of ACC data is", Xt_acc.shape)
print("[INFO] shape of GYR data is", Xt_gyr.shape)
print(f"[INFO] {Xt_acc.shape[0]} windows with {Xt_acc[0].shape[1]} sample each (ti
```

```
[INFO] shape of ACC data is (7265,)
[INFO] shape of GYR data is (7265,)
[INFO] 7265 windows with 4 sample each (time stamps and 3 axis accelerometer)
```

You can discard the time column with e.g.:

```
Xt_acc = Xt_acc[:,:,1:]
```

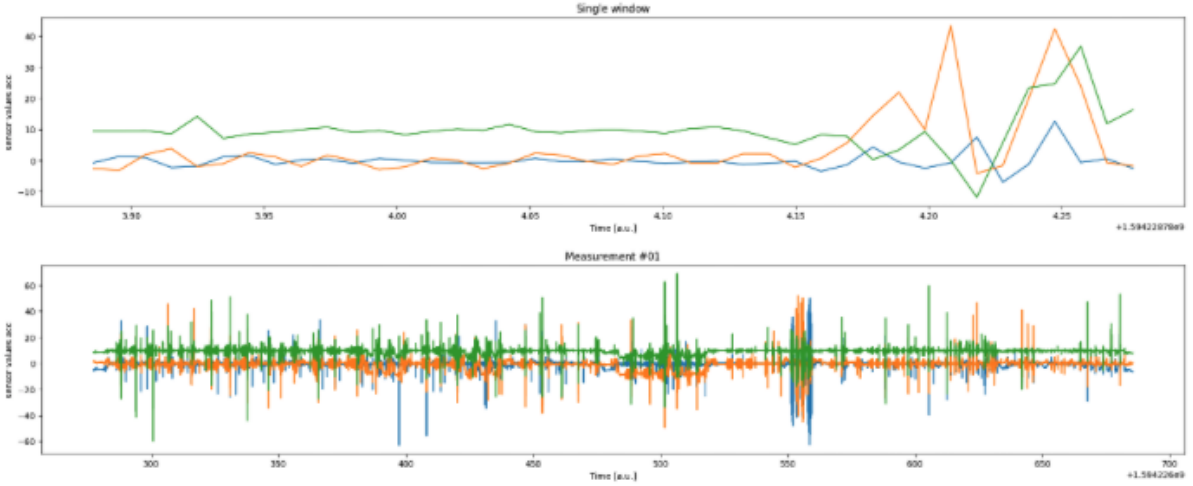
Plot the data

2.2 Plot the Data

[37]:
```
import matplotlib.pyplot as plt

# plot a sample
plt.figure(figsize=(24,4))
plt.title(f"Single window")
t = Xt_acc[70][:, 0]
x_win = Xt_acc[70][:, 1:]
plt.plot(t, x_win)
plt.xlabel('Time [a.u.]')
plt.ylabel('sensor values acc')
plt.show()

# plot a measurement
plotme = data_dict["01"].acc.ts
t = plotme[:, 0]
x_mea = plotme[:, 1:]
plt.figure(figsize=(24,4))
plt.title("Measurement #01")
plt.plot(t, x_mea)
plt.xlabel('Time [a.u.]')
plt.ylabel('sensor values acc')
plt.show()
```



Data Preprocessing: filter out specific points by label

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1.4. 3. Preprocess the Data

[19]:
```
from fhgutils import filter_labels, one_label_per_window, summarize_labels
```

1.4.1. 3.1 `filter_labels`

- filter out labels [-1]
- also filter out whole windows, in case there is no majority label
- e.g. window length of 5, labels could be [1,1,1,1,0] -> okay. but if [1,1,0,0,2] -> discard window.

[20]:
```
values, counts = np.unique(y_acc, return_counts=True)
for val, count in zip(values, counts):
    print(f"[INFO] label {val} with {count} samples")
```

```
[INFO] label 2.0 with 33998 samples
[INFO] label 3.0 with 14588 samples
[INFO] label 4.0 with 12588 samples
[INFO] label 5.0 with 5614 samples
[INFO] label 6.0 with 3097 samples
[INFO] label 7.0 with 3672 samples
[INFO] label 8.0 with 223675 samples
[INFO] label 14.0 with 633 samples
```

[21]:
```
Xt_acc_f, Xc_acc_f, y_acc_f = filter_labels(labels=[-1], Xt=Xt_acc,
                                            Xc=Xc_acc, y=y_acc)
```

```
[INFO] original Xt: 7265 (41, 4)
[INFO] filtered Xt: 7259 (41, 4)
```

Flatten labels

Uses majority vote to determine window-level labels

- For further label conversion, see OneHotEncoder in scikit-learn

1.4.2. 3.2 `one_label_per_window`

- flatten labels of windows to the majority label
- `[1,1,1,1,2]` -> 1. bad if you've got `[0,0,0,0,0,1,1,1,1,1,1]` -> 1, this creates anomalous samples of class 1

[22]:
```
print("pre", y_acc_f[5])
y_acc_f = one_label_per_window(y=y_acc_f)
print("post", y_acc_f[5])
```

```
pre [2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2.
 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2.]
flattened 8 labels: [ 2  3  4  5  6  7  8 14]
post 2
```

Summarize labels

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You may combine annotations into a new class to augment the dataset from real data.

1.4.3. 3.3 `summarize_labels`

- some labels are basically very similar, like "pull_trigger, pull_trigger_air" for the Pneumatic Rivet Gun
- same action, but once holding the tool in the air, once using it on a workpiece.

[43]:
```
summarylabels = {5: [0, 1]}
y_acc_f_sum = summarize_labels(y_acc, summarylabels)
```

```
[INFO] Summarized labels from [ 2.  3.  4.  5.  6.  7.  8. 14.] to [ 2.  3.  4.  5.
6.  7.  8. 14.]
```

[44]:
```
X_trans.shape
```

[44]:
```
[29060]
```

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Summary

Multi-modal
Tool Tracking Dataset

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Summary

- Materials
- Motivation
- System description
  - Hardware platform
  - Sensors
- Hand-held tools
  - Tools
  - Important sensors
- Time-Series Dataset
  - Tools
  - Recordings
  - Annotations
  - Folder structure and data
  - Data loader