POLITECNICO MILANO 1863

SPIN TEST: *Assessment of compliancy for centrifugal blood pumps*

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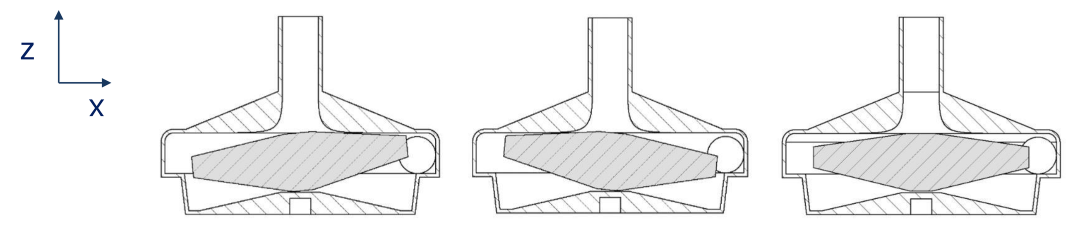
CASE STUDY

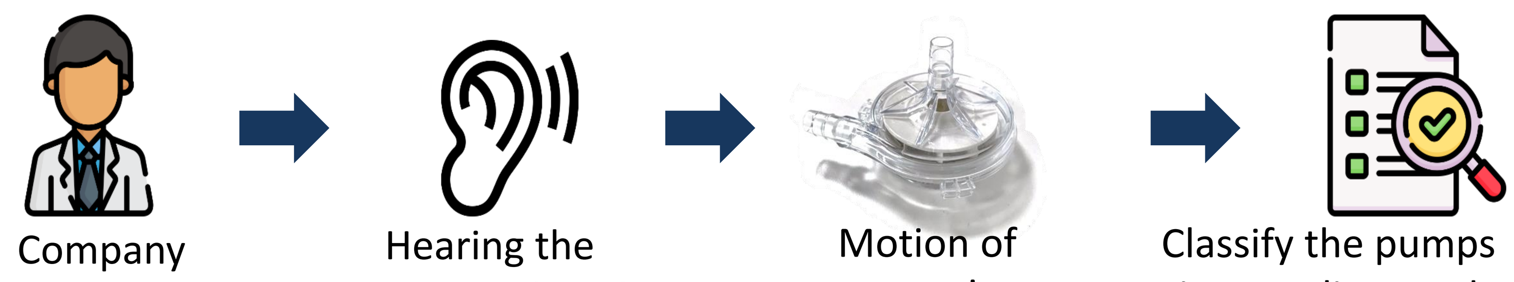
Centrifugal Blood Pumps: devices used during extracorporeal circulation; the blood flow enters from the inlet of the pump and is pushed by the rotor in such a way as to exit through the outlet, oriented at an angle of 90 ° to the inlet

Problem: movement of the impeller which tends to make a flickering movement along the z-x and z-y plane. This could cause haemolysis and thrombi



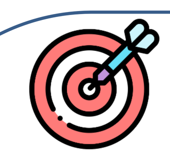
Solution: Spin Test to quantify the flickering of the impeller and classify the pumps between compliant and non-compliant

Today's approach



Company operator → Hearing the noise produced by the pump → Motion of pump's impeller → Classify the pumps in compliant and not compliant

GOAL

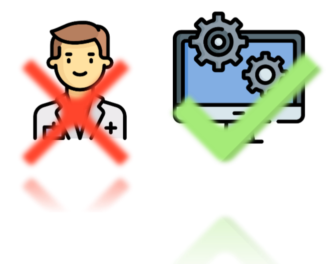


Find a **STANDARDIZED**, **AUTOMATED** and **NON-DAMAGING** protocol to test the pump in order to assess its acceptability

1. Optimize the process
2. Standardize the modality to eliminate the intra-subject variability
3. Not distructive test
4. Reproducible
5. Not invasive approach

Impact: this would mean increasing the efficiency of the the process in terms of time and human resources

New approach: the operator no longer has a determining role in the classification of the pumps. In fact, through a machine learning model, the classification becomes more objective



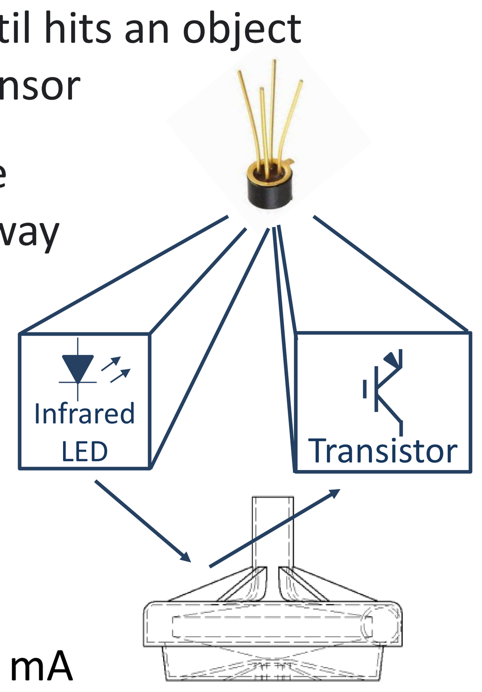
MATHERIALS AND METHODS

OPTICAL PROXIMITY SENSORS

Explanation: when a voltage is applied, the diode emits IR light that propagates until hits an object and it is reflected towards the sensor

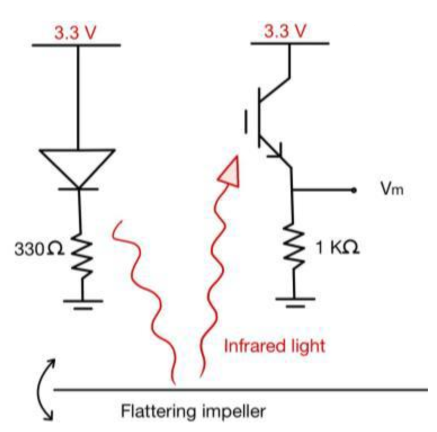
Efficacy: measure how much the impeller approaches or moves away from the sensors

OPB730F sensors



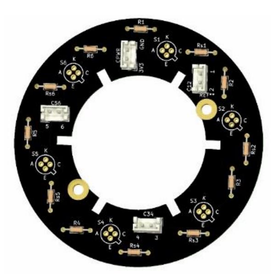
- ✓ Linearity range [2.5-10mm]
- ✓ Filter
- ✓ Internal barrier
- ✓ Max Input diode's current = 50 mA
- ✓ R diode > 36Ω

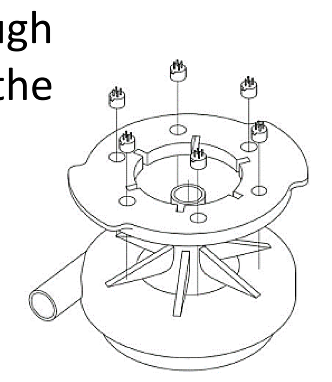
Every sensor used is associated to a circuit



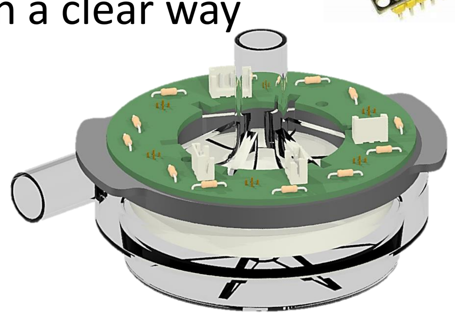
PCB AND DEVELOPMENT BOARD

PCB (Printed Circuit Board): 6 sensors were used to achieve a precise measure of the impeller fluttering.
The PCB reduces the extension of the circuits and makes the set-up compact.
The PCB is then fixed to the pump through a support which allows maintaining the sensors in the right position





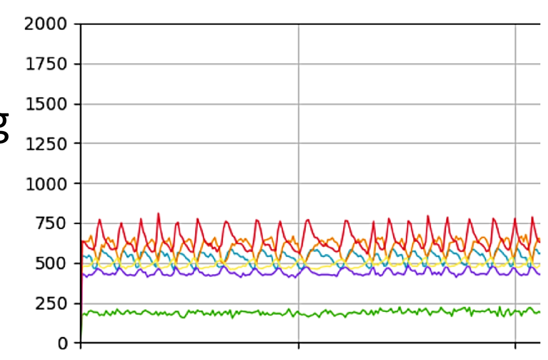
Development Board: the development board is what brings the output signals of the sensors as input for the graphical interface. In this way the signals are displayed to the operator in a clear way



MACHINE LEARNING

Data Acquisition: the set-up with is used to register the signal from 51 pumps. These were divided a priori between compliant and non compliant.

Data acquisition was performed using two kinds of test: imposing a rotation of 100 rpm or 500 rpm, both times for 5 seconds



CNN Model Implementation

1. The raw data obtained from the sensors is elaborated using data augmentation, in this way it is obtained the training set
2. Preparation of test-set
3. Definition of model architecture

Model Tuning: defining optimal parameters to get the best result with the model architecture chosen. The parameters to be optimized are: dimension of the windows used to elaborate the data, filters' dimension and their number

RESULTS AND DISCUSSION

MODEL IDEA

The classifier works applying a simply threshold:

$$C = \begin{cases} 1, S \geq 0.5 \Rightarrow Compliant \\ 0, S < 0.5 \Rightarrow Non\ Compliant \end{cases}$$

The confidence of the classificator is given by:

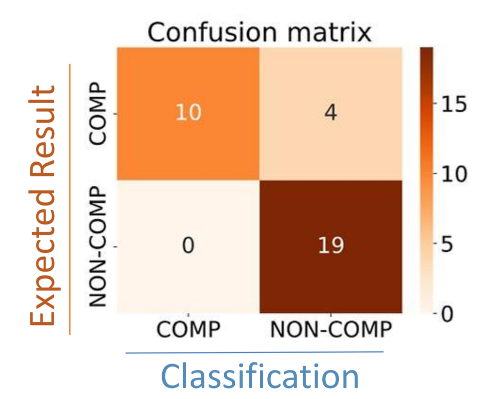
$$K = 2 \cdot |S - 0.5| \cdot 100$$

THE DATASET

Initial dataset is composed by 33 pumps:

- 11 pumps are used to calculate the the accuracy of the model
- 22 pumps are used for the training phase

Initial Results	
29 pumps	Properly classified
4 pumps	False negative
Accuracy	0.88



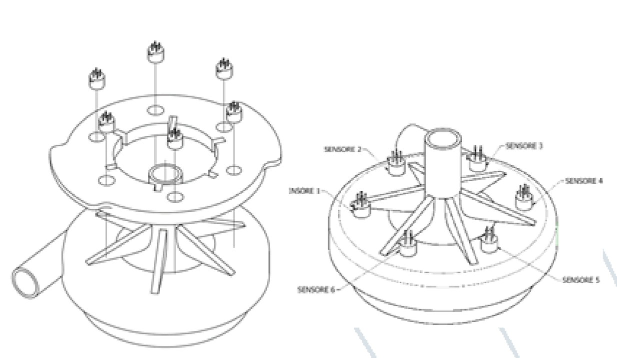
VALIDATION TEST

Test on-site at Qura s.r.l. to validate our model: 13 pumps tested not included in the training dataset

Results	
11 pumps	Properly classified
2 pumps	False negative
Accuracy	0.84

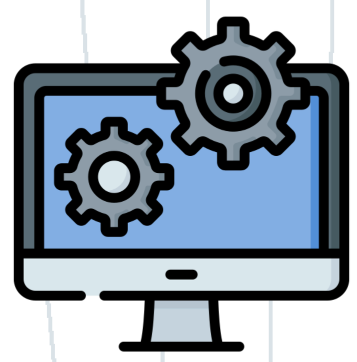
The results confirm the validity of the model

FINAL PROTOCOL

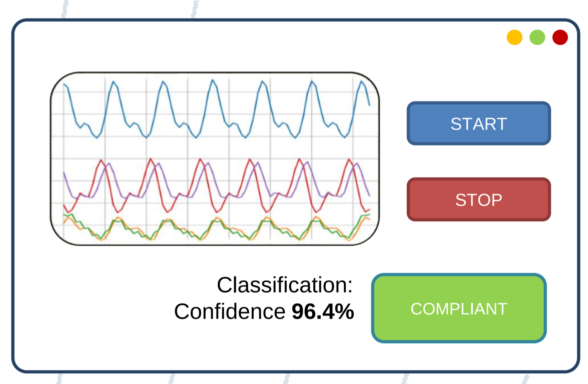


Placing the PCB and the sensors' support on the pump

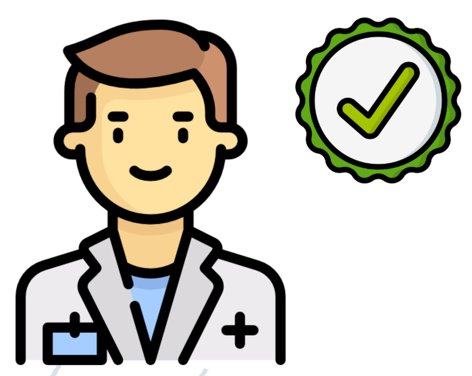
Mount the pump on the driver and set test velocity



The classifier, based on the training dataset, classifies the pump in compliant or not compliant



The graphic interface shows the result of the classification with the confidence and the signals acquired



The user can easily and fastly classifies the pumps using a standardized and automated method