Universidade Federal de Minas Gerais
Escola de Engenharia
Curso de Graduação em Engenharia de Controle e Automação

EHDA closed loop control system based on real time non-visual spray mode classification

Relatório de Atividades 4
Projeto Final de Curso

Orientador: Vitor Angelo
Supervisor: Luewton L F Agostinho
Aluno: João Pedro Miranda Marques
Matricula: 2017050495

February 14, 2023

1 Summary

Electrohydrodynamic Atomization (EHDA), also known as Electrospray (ES), is a way to disintegrate a liquid into droplets by exposing it to a strong electric field. EHDA surveys have contributed as an important tool for the development of water technology (thermal desalination and metal recovery), material sciences (nanofibers and nano spheres fabrication, metal recovery, selective membranes, and batteries), and biomedical application (droplet encapsulation). Besides that, the project is merged with the Energy Transition strategy and Innovation Agenda Agriculture, Water, and Food, Key Enabling Technologies (KETs). Although, there are EHDA applications in industry, stabilizing the cone-jet spray mode is done empirically and based on mean current measurements.

The electric current flowing transported by the spray reveals characteristic shapes for different spray modes. Those shapes cannot simply be summarized by its mean value. In figure one we can see an example of cone-jet mode electrospray.

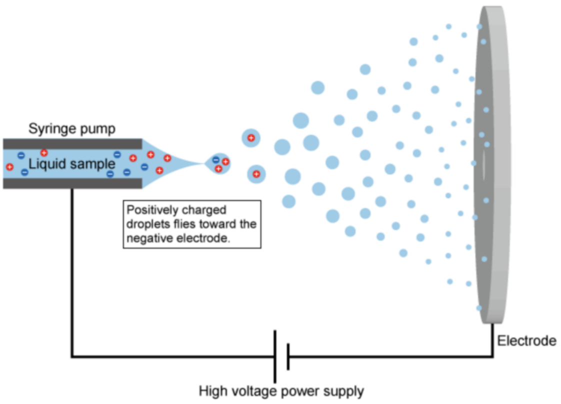


Figure 1: EHDA

Signal processing techniques can allow a non-visual classification of the spray mode based on the electric current shape. The spray process imposes noise and random sequences on the measured signal making its classification not a trivial task.

Industrial applications demand automated stabilization of a spray mode. This can be achieved by a closed-loop control system. Figure 2 shows the control model implemented in this project.

The setup used for this project can be seen in the Figure 3 and 4. To run the experiment automatically it is used a computational processing machine to integrate the peripherals and run their routines, system sensors such as the oscilloscope and the high speed camera and also the system actuators which is represented by the high voltage power supply and the syringe pump.

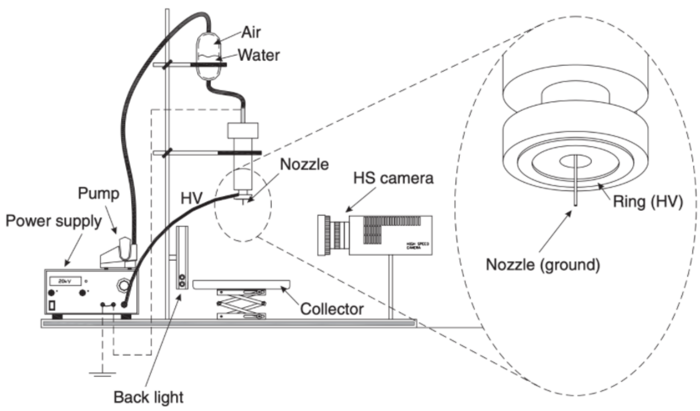


Figure 2: System Diagram

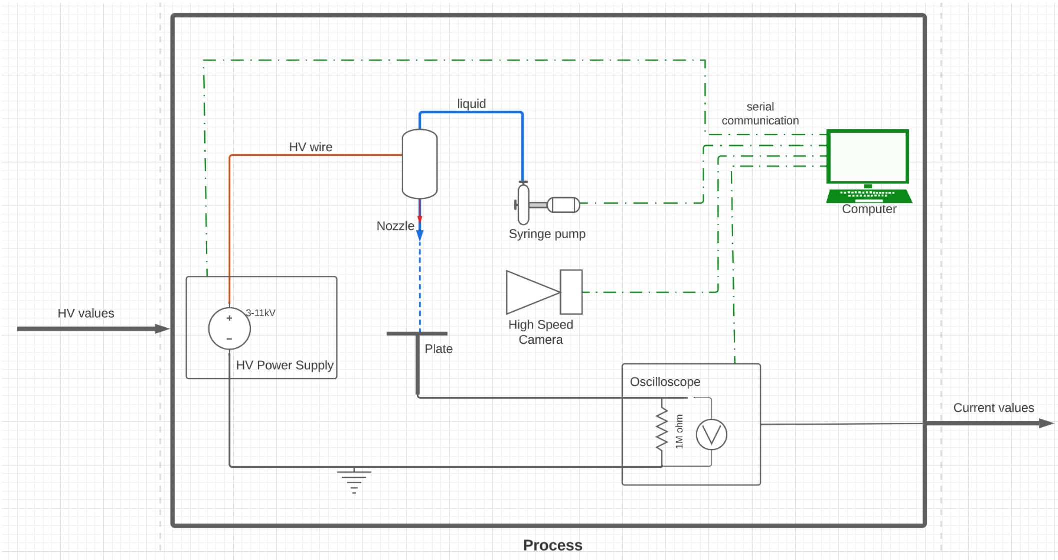


Figure 3: System Automation Diagram

Automated classification of the spray mode is a crucial part of a control system same as the development of an appropriate control algorithm. Signal processing implementations of previous projects of the NHL Stenden Water Technology group are showing good classification results. Further research is necessary to improve the classification accuracy and research and implementation of a suitable classification algorithm. Because of that, this work is being done by the Water Technology Group at NHL Stenden University of Applied Sciences and in combination with Dutch companies to match analysis possibilities with knowledge and infrastructure availability.

2 Metodology and Results

The following subsections are about the work done in this 4rd part of the project.

2.1 Save experiment in real time

With the mapping routine the experiments time and data size started to make difference. One experiment generates in average 6GB of data and takes arround 1,5 hours to complete. The saving section was working with the python json library and with the function json_dump(). One thing about using json objects is that the structure should be closed. The function json_dump() need the complete json file in order to save it. For that the routine was saving all the data in python dictionaries. And after that creating and saving the json file. Two new problems were happening. If the experiment crashes in the middle all the experiment data get lost. And it is not clear if the operational system or python kernel will support all the experiment data in program memory.

To solve that a new thread was created *save_data_thread()* in order to save each sample in a selected file in the non-volatile memory. Also was needed to use another python json library developed for streamming data in json structure in a file. It is called *jsonstreams*.

With those new improvements we are abble to:

- Save data for big experiments. Depending just on the non-volatile memory storage.
- Use a raspberry pi for processing and saving big experiments.
- Interrupt and exit an experiment in real time and get the data saved.
- Less waiting time after the experiment to save all the data.

The new software design can ben represented in the model showed in Figure 2.

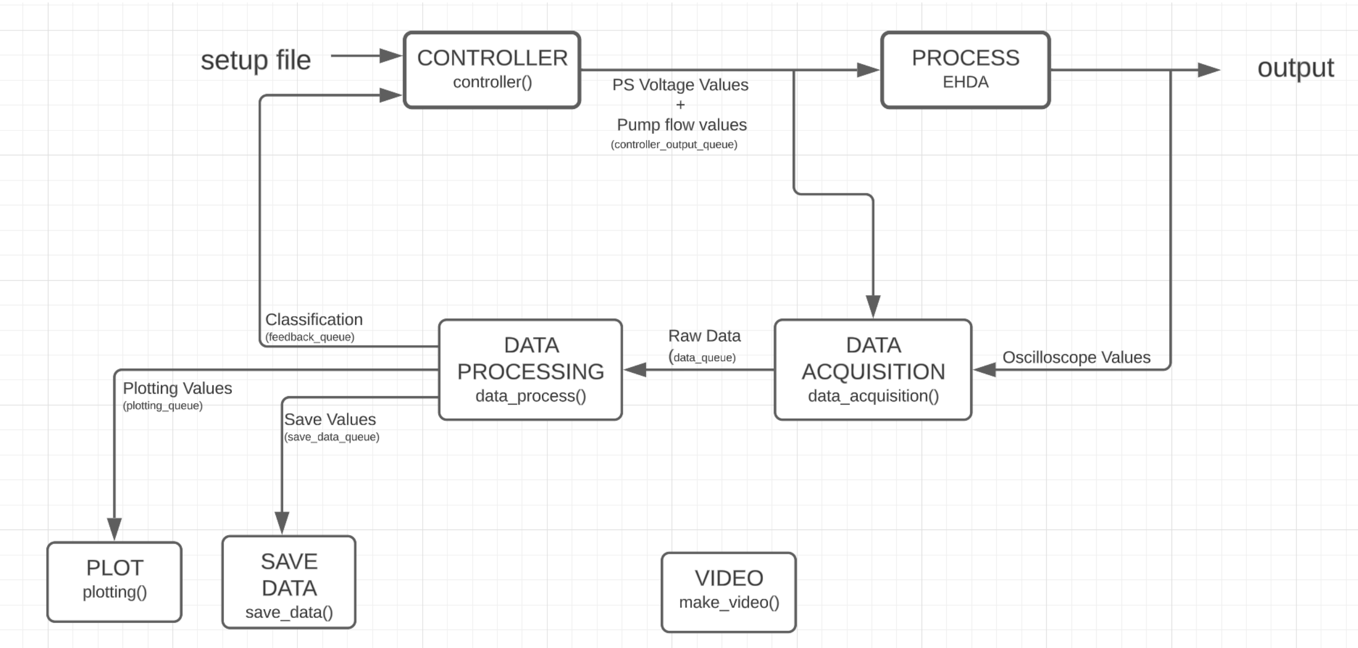
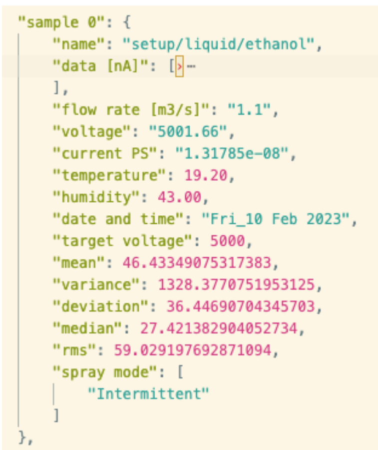


Figure 4: Control model implemented in software

2.2 Saved Data Structure

With the new streamming model of saving a new structure of the collected data were created. Instead of having all data measurements values and after all data processing values we now are saving for each sample the measurements and processing values. The structure of the



```
"sample 0": {
    "name": "setup/liquid/ethanol",
    "data [nA]": [>…
    ],
    "flow rate [m3/s]": "1.1",
    "voltage": "5001.66",
    "current PS": "1.31785e-08",
    "temperature": 19.20,
    "humidity": 43.00,
    "date and time": "Fri_10 Feb 2023",
    "target voltage": 5000,
    "mean": 46.43349075317383,
    "variance": 1328.3770751953125,
    "deviation": 36.44690704345703,
    "median": 27.421382904052734,
    "rms": 59.029197692871094,
    "spray mode": [
        "Intermittent"
    ]
},
```

Figure 5: Output data json structure

To work with this data I'm using pandas Dataframe. With the command: pandas.read_json("PATH", orient='index').

The json file is good to store the data and to read the file. But as it is getting a lot of data working with pandas Dataframe is being way faster. Also saving the dataframe in a compressed type of file called feather is much faster to work with the data.

2.1 Raspberry pi

2.1 Mapping experiments

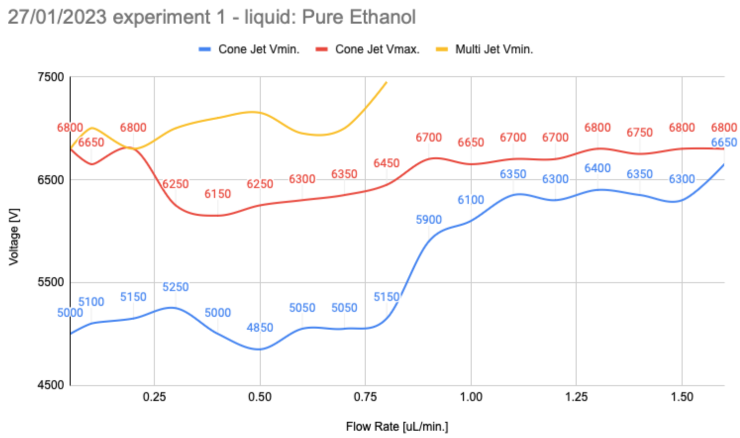


Figure 6: Control model implemented in software

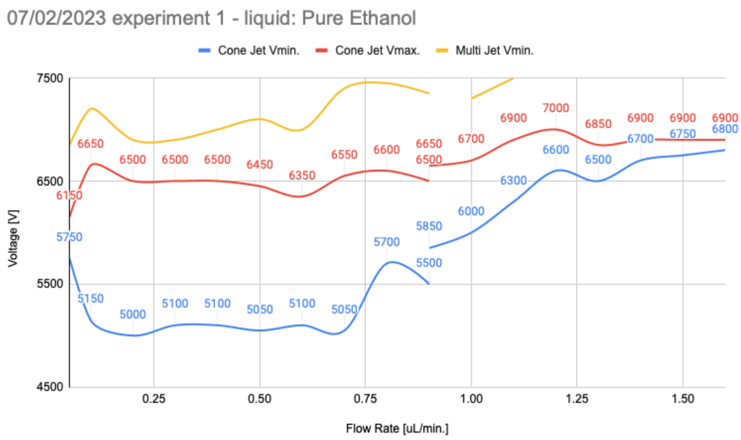


Figure 7: Control model implemented in software

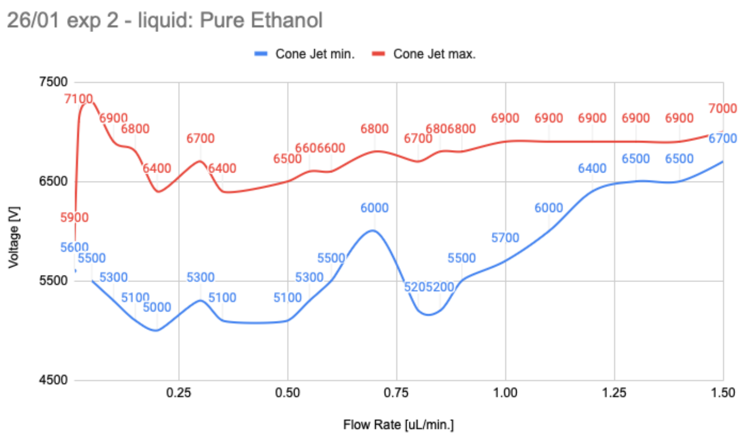


Figure 8: Control model implemented in software

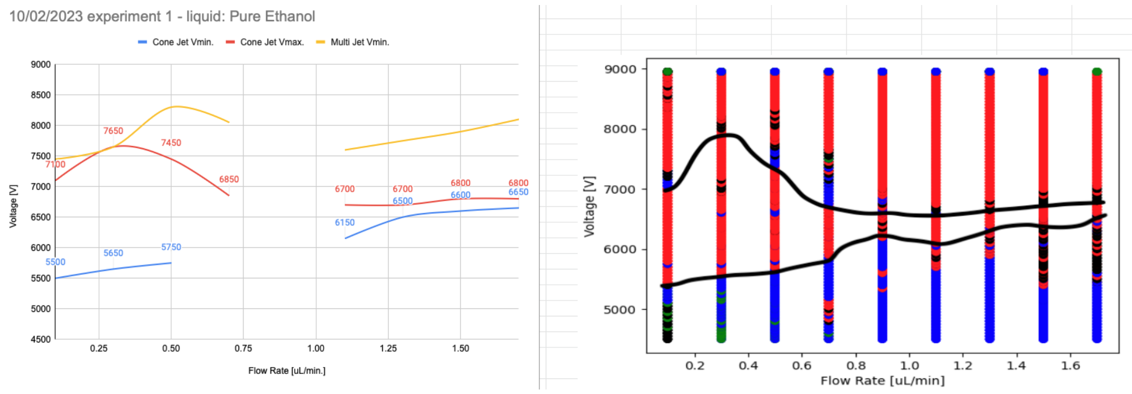


Figure 9: Control model implemented in software

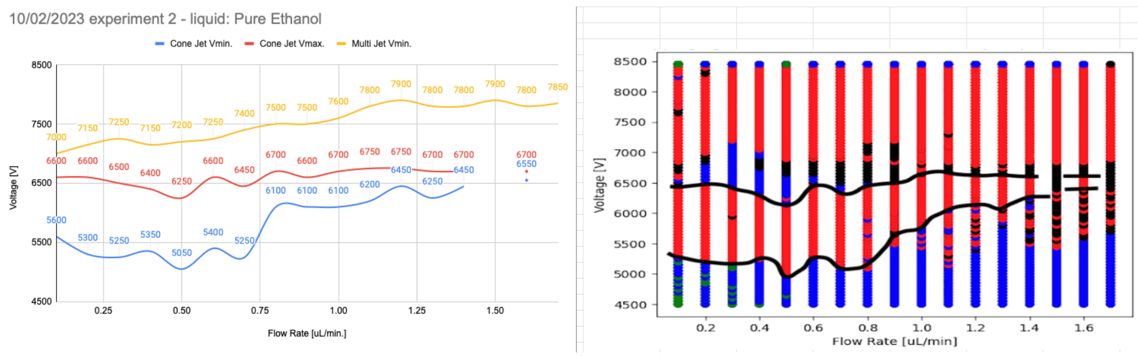


Figure 10: Control model implemented in software

2.1 Correctly Join threads and qeues

3 Conclusion

The integration with the pump machine in the automatic system brings a new dimension of possibilities in this project. The goal at the moment is to improve the algorithm in order to be capable of scanning the stable region of cone jet mode in the Voltage X Flowrate map. After that define the middle point in the stability island to set as a setpoint to our control system. The control system will be capable of rejecting noises and disturbance in the system in order to keep always in the stable cone jet spraying mode.

For further goals we have:

- Save the experiment data in a file while running the experiment. This will prevent lost of data if the program crashes and also not overflowing the program memory.
- Install and run the experiments in a raspberry pi portable computer running Linux.
- Study about the fourier transform peaks and how it can be used in the classification and in the mapping.
- Improve the classification and routine performance.
- Optimize the controller.

Until the moment the project has been shown good results. The map routine, the control routine and the classification are already implemented and working. Now its more about improvements to get better accuracy in results.