UNIVERSITÀ DI TRENTO

Final Dissertation

BACHELOR'S DEGREE IN COMPUTER SCIENCE

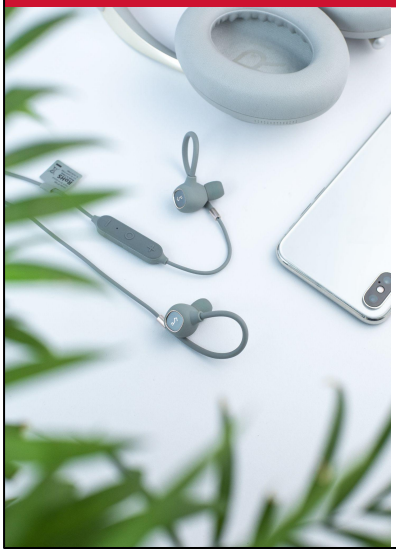
A WEB GRAPHICAL USER INTERFACE FOR THE PACKET-LOSS-CONCEALMENT TESTBENCH TOOL

Student	Supervisor	Co-Supervisor
Stefano Dallona	Prof. Luca Turchet	Ing. Luca Vignati

Good afternoon to everyone, first of all I would like to **thank all the committee members** for attending the discussion of my thesis work.
My name is Stefano Dallona, I'm a **student of the Bachelor's Degree in Computer Science** and for the entire duration of my studies I've worked full-time.
The **title** of my thesis is: "**A Web Graphical User Interface for the Packet-Loss-Concealment Testbench Tool**".
My work was **supervised by professor Turchet and by Luca Vignati**.
What really **attracted me** about this thesis was the **immediate applicability** and the fact that the **topic** was completely **new** to me**.**

UNIVERSITÀ DI TRENTO

Introduction



1 **Context**
PLC Testbench, a tool to compare Packet Loss Concealing algorithms

2 **Problems**
Interaction only possible at code level in an IDE
Output information not integrated

3 **Solution**
Development of a graphical user interface

The **context** in which this thesis was born is the **PLC Testbench**, a tool to compare Packet-Loss-Concealment algorithms developed by Luca Vignati.
PLC algorithms try reconstruct the lost portions of audio streams to **provide acceptable quality on lossy connections**.

The **biggest problems** with the PLC Testbench were that:

- the **interaction with the tool** was **possible only** at **code** level;
- the output **information** was **not integrated**, making the **analysis inefficient**

The development of a **Graphical User Interface** was seen **as a solution** to these problems.

UNIVERSITÀ DI TRENTO

Purpose of the Thesis

Developing a **GUI for the PLC Testbench** tool
to boost up

QUALITATIVE and **QUANTITATIVE**
comparison of PLC algorithms

by making the **INTERACTION with the tool**
EASY, EFFECTIVE and EFFICIENT

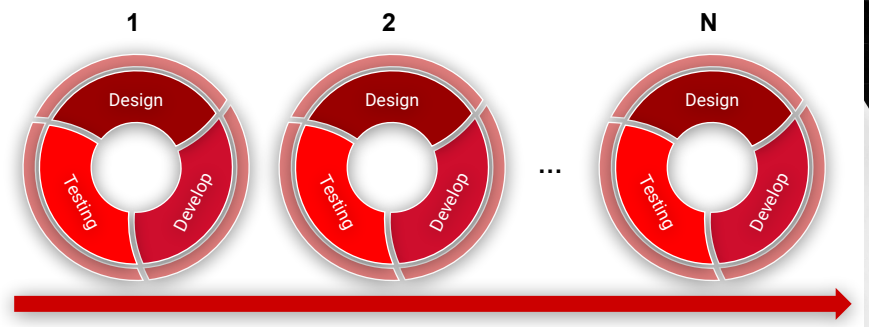
The **purpose** of this thesis work was therefore **developing a GUI** for the PLC Testbench to boost up the qualitative and quantitative comparison of PLC algorithms by **making the interaction** with the tool **easy**, **effective**, and **efficient**.
Qualitative comparison mainly consists in visually **comparing waveforms and spectrograms**, and in **listening to audio files**.
Quantitative comparison is essentially **based on metrics** calculated the reconstructed audio files.

UNIVERSITÀ DI TRENTO

Methodology

Iterative agile development process

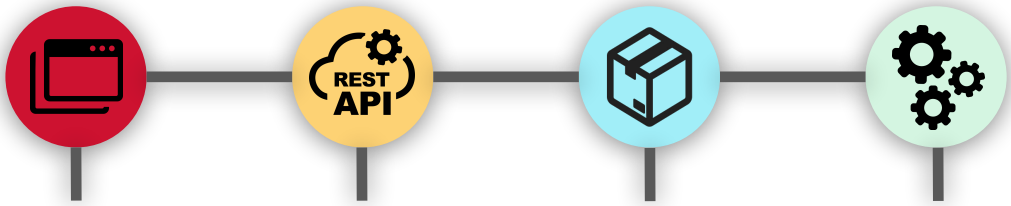
- short release cycles
- focus fast feedback
- < risk of useless development



From a methodological perspective, it was decided to adopt an **iterative agile development process** composed of **short cycles of design, develop and testing** phases.
This helped keeping the focus on **small and clear objectives** and getting **fast feedback**, thus **minimizing** the risk of developing **useless functions**.

UNIVERSITÀ DI TRENTO

Technologies



Front-end
Javascript + React

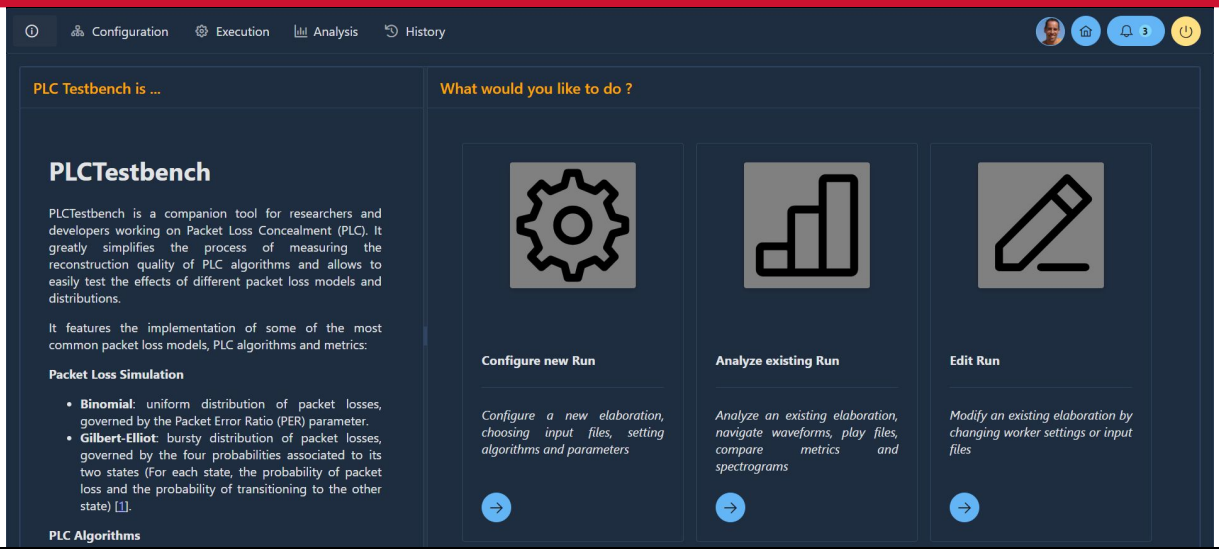
Back-end
Python + Flask

Packaging & Distribution
Docker

Build & Deploy
Circle CI pipelines

The GUI was developed through a **Web application**, made of **two layers**: a **frontend, implementing the graphical part of the UI,** written in JavaScript and based on React framework and a **backend, implementing services over a REST API**, written in Python and based on Flask framework.
Bundling and distribution were addressed **by containerizing** the application **as a Docker image**, while for **build and deploy** I leveraged Circle CI's **pipelines as code**.

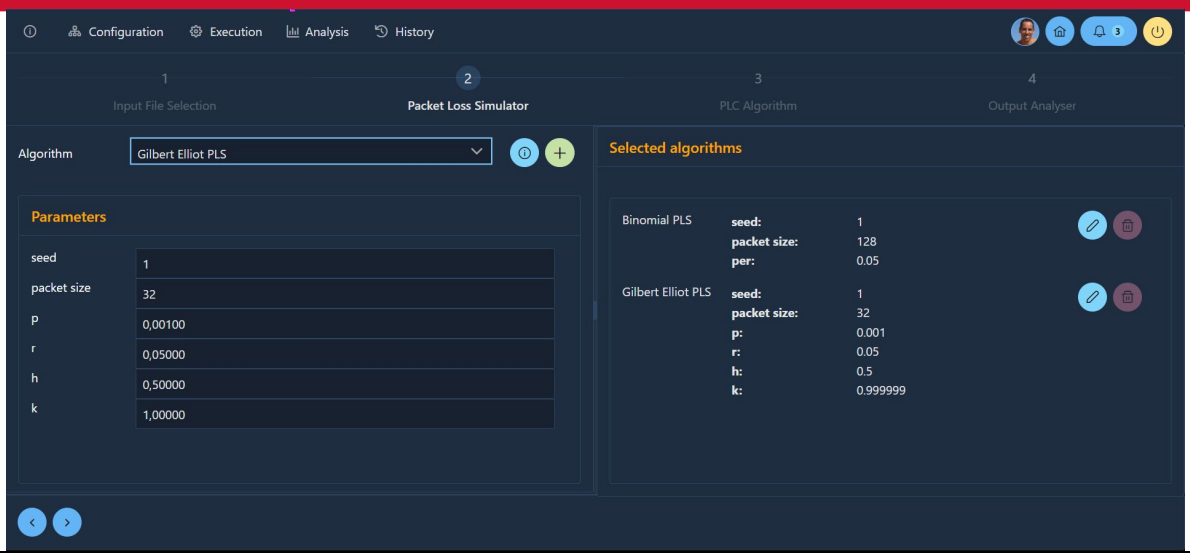
GUI - Landing Page



Now time has come to have a look at the application interface.
This is the **landing page** which addresses **two** main **purposes**:

- helping the user to **develop** a **proper mental model of the software** by providing on the left a **short help page;**
- putting the user in condition to **start using the tool immediately** by displaying on the right a **list of** the **most relevant operations** supported by the application, with a **direct entry point** to the functions.

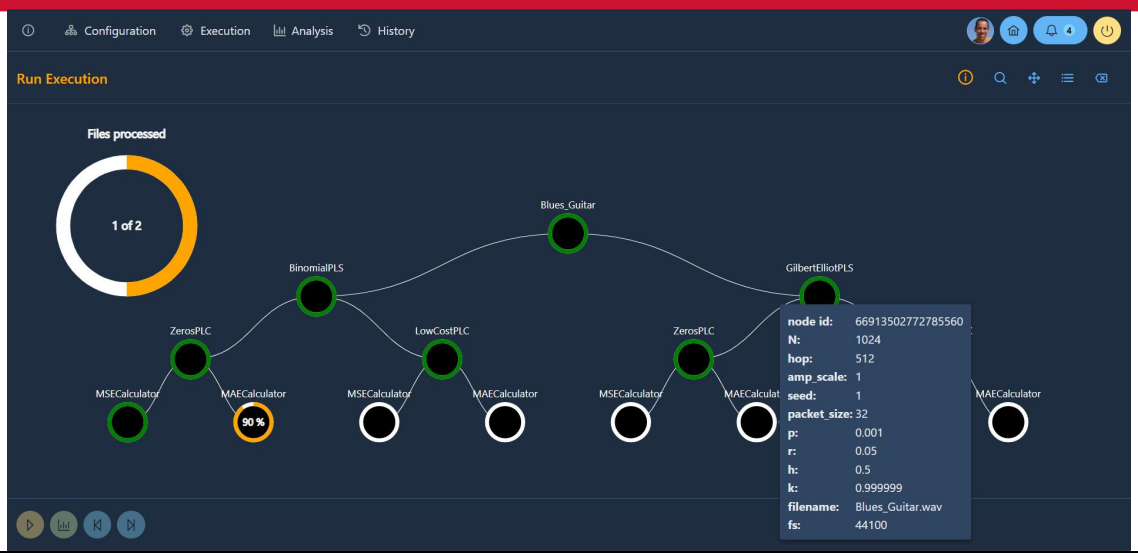
GUI - Configuration Module



This **screen** instead is intended **to guide the user** through the **configuration of an elaboration** focusing on three objectives:

- **fast and effective interaction:** pursued with **sensibile defaults for** the **settings** and **keyboard shortcuts**;
- **clarity**: pursued by splitting the configuration process into **multiple sequential steps;**
- **adaptability:** achieved **by** implementing **dynamic discovery of** the **algorithms and settings**, thus supporting testbench extensions with no changes to the code.

GUI - Execution Module

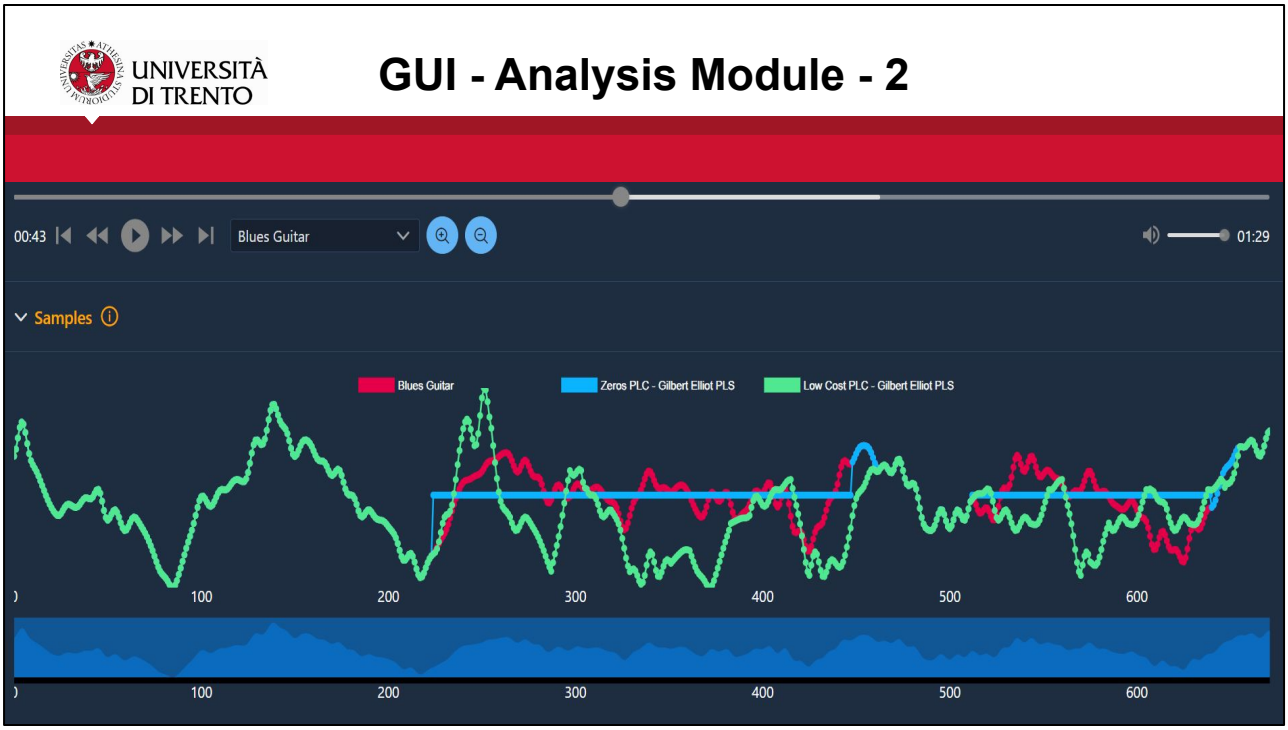


A PLC Testbench **elaboration** can be represented **as a forest of trees,** each corresponding to a single input file. Processing can take a long time, thus **progress monitoring** is **essential**.
Since the **structure identical for all the input files** it was decided to display progress at two different levels of detail: **overall progress** and **progress within a single file** processing. The **settings** of each elaboration step can be inspected by **placing the mouse pointer over** the corresponding **node**.

GUI - Analysis Module - 1

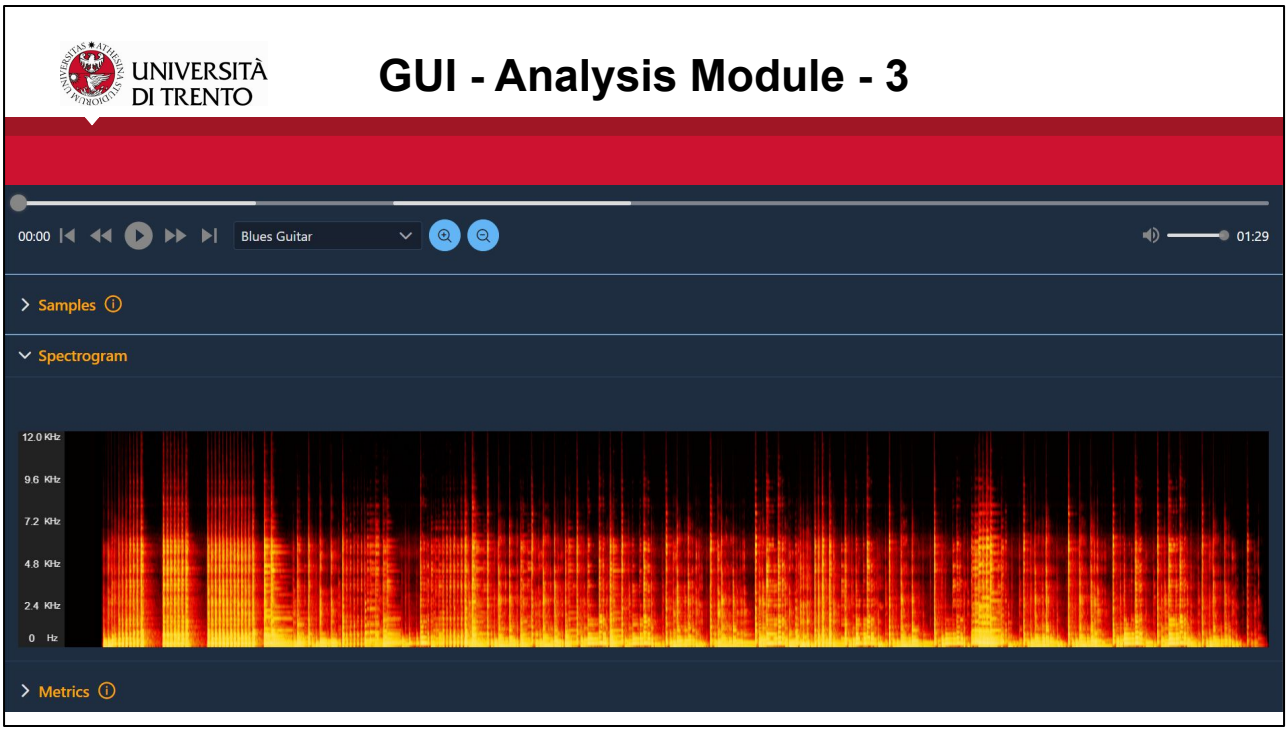
In the analysis module the **waveforms of all the versions of a** given **input file** are **displayed on the same chart**, **together with the lost packets' regions.**
Each **waveform** can be **shown or hidden independently**.
Each version of the **audio file** can be **played to evaluate** the **perceived quality of the reconstruction.**
Zoom-in function supports any **level of detail**.

GUI - Analysis Module - 2



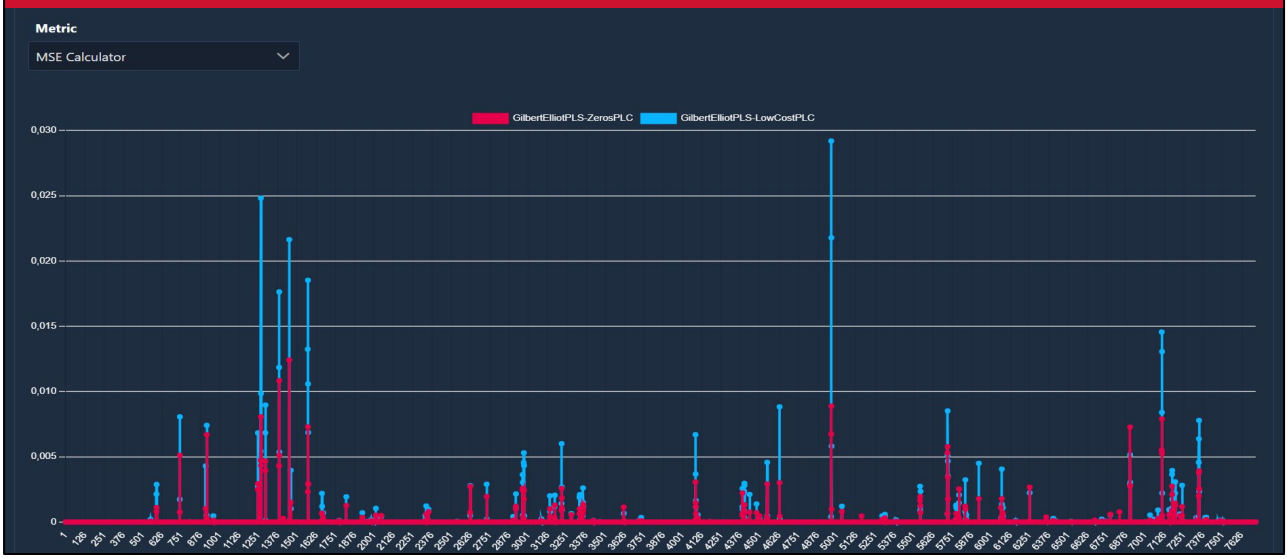
In the **"Samples" view** in the analysis module at the maximum zoom level **single audio signal's samples** can be discriminated. **Zoom-in and zoom-out** are supported by dragging the handles in the bar below the chart. Each **waveform can be shown or hidden** independently.
The more the original and the reconstructed **signals overlap**, the more the **reconstruction** can be considered **accurate**.

GUI - Analysis Module - 3



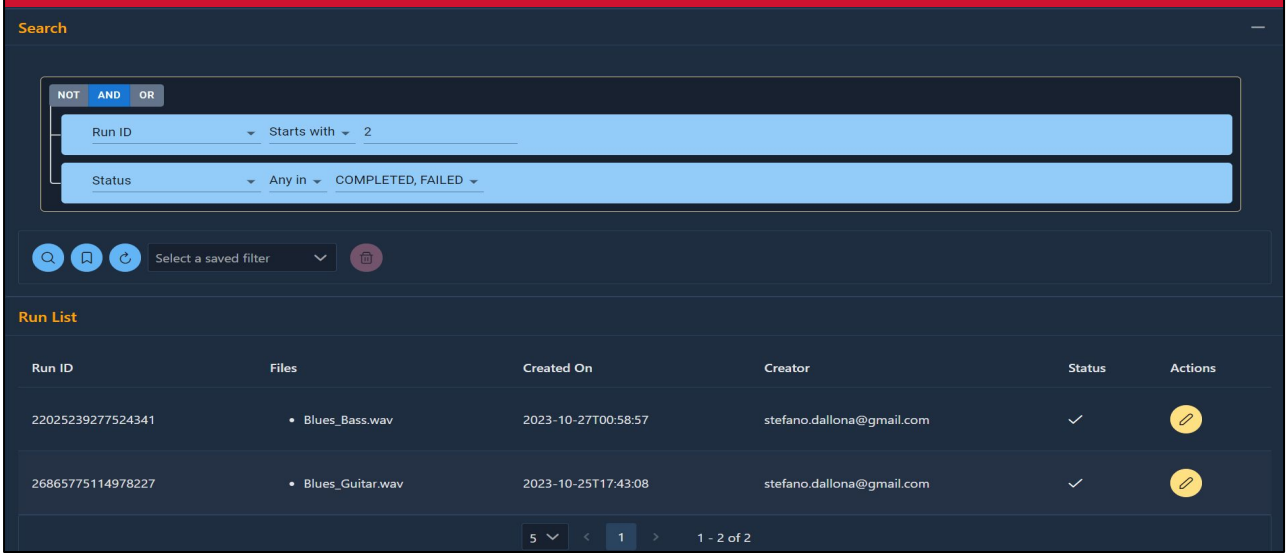
For each audio file a **spectrograms** can be displayed, representing the **composition of the audio signal over time as a color map**, where **brighter colors** indicate a **greater intensity of the corresponding frequencies**.

GUI - Analysis Module - 4



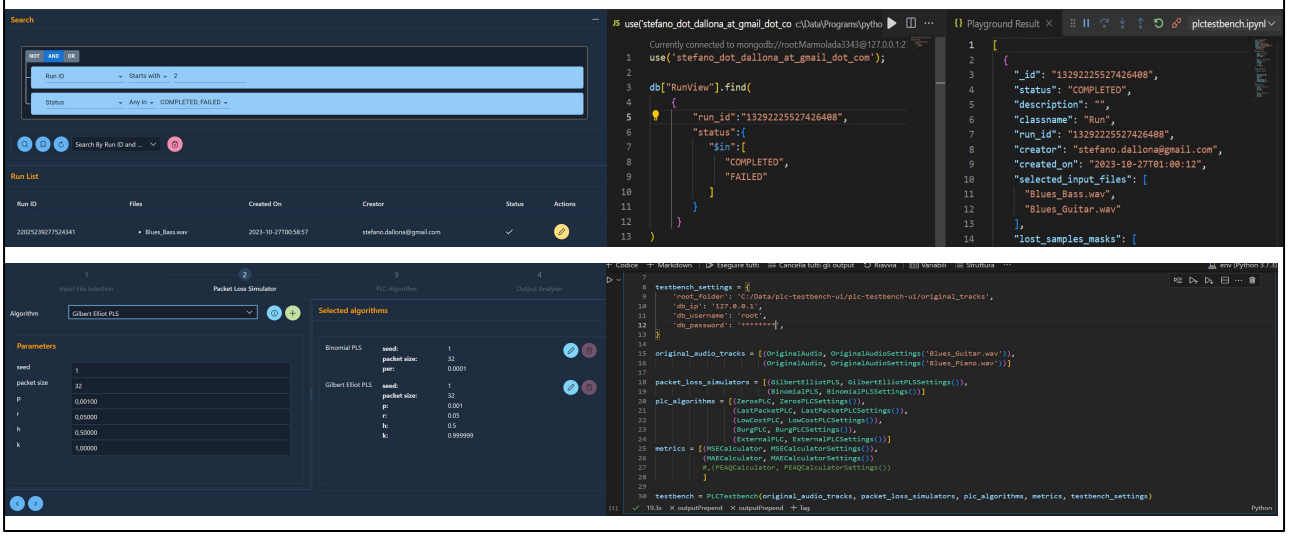
Output metrics are **calculated on each original and reconstructed audio file**. They can be grouped into **two categories**: **linear** metrics, producing a **time series for each** audio **file**, and **scalar metrics**, producing a **single value for each audio file**. The data to be displayed can be customized by clicking on the legend items.

GUI - Search Module



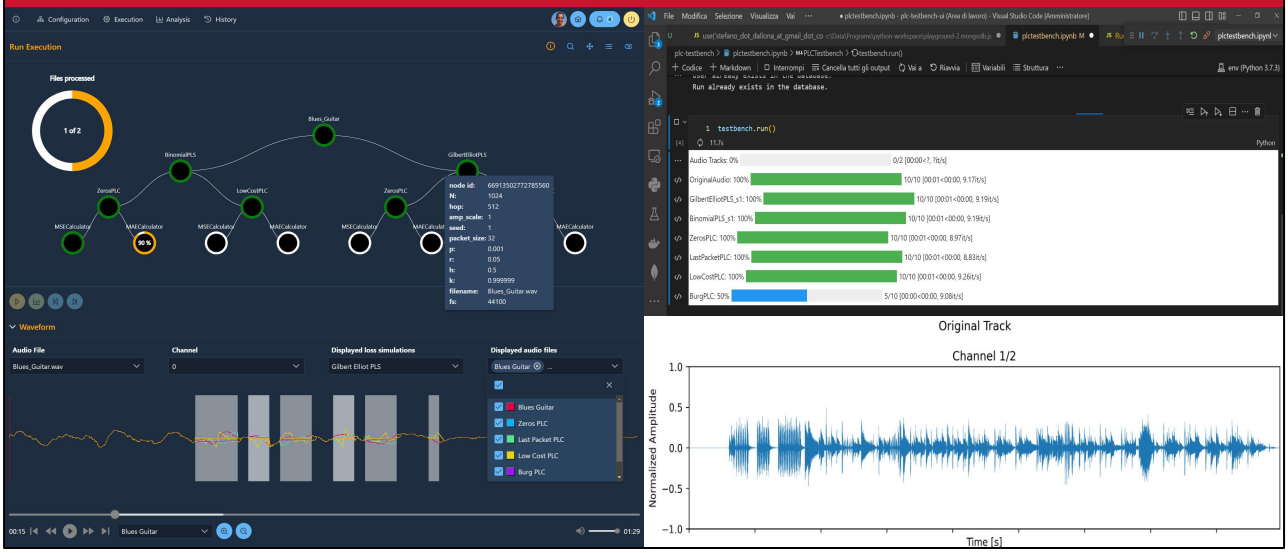
The search module allows the user to **navigate through the list of the elaborations** or to **build**, **save** and **re-execute** specific **queries**.
Queries can be built visually by **combining** multiple **conditions using logical operators**.
Each **condition** can be **based on any field** of the elaboration **or** on any **setting** of the referenced algorithms.

GUI vs Native Interaction - 1



This slide shows a visual **comparison of** how elaborations inquiry and configuration are performed **in the web GUI versus** how they are carried out through **the native** testbench **interface**.
On the left in the **GUI** supports the interaction is completely **visual** while on the right, in the **native mode,** the same operations have to be performed **at programming level**.

GUI vs Native Interaction - 2

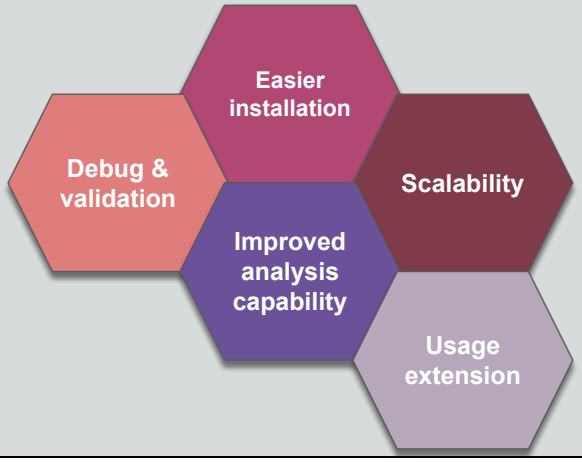


Here the **same comparison** Is applied to the **progress monitoring and results analysis use cases.**
Also in this case the web **GUI** provides a more convenient and effective interaction by presenting **output information** in a **more detailed and integrated** way.

UNIVERSITÀ DI TRENTO

Results

Benefits brought to the PLC Testbench tool



The most relevant benefits brought to the PLC Testbench tool by this thesis work can be summarized as follows:

- a thorough **debug and validation** of the testbench was carried out during of the project;
- the **analysis capabilities** of the tool have been extended and **improved in** terms of **quantity and quality** of the information;
- tool **installation** has been made **easier** by encapsulating the **complexity in** the **build** process **of the docker image**;
- the **application** has been made **more scalable by** making **distributed deployment** possible;
- the possibility to **use** the tool has been **extended** to **users with no expertise in Python programming.**

UNIVERSITÀ DI TRENTO

Future Work

A few ideas

- *Extensive validation with users (*)*
- *Support for additionals audio formats*
- *Search functions on output results*
- *User collaboration use cases*
- *Data export*

(*) A first preliminary but very positive feedback has been received from experts at the IS2 2023 Conference in Pisa

Despite being **fully operational and exposing all the** current **functions of** the underlying **PLC Testbench**, the web GUI still has a lot of **room for improvement**.
A few ideas for **possible future enhancements** are:

- Extensive validation with users;
- Support for additionals audio formats;
- Search functions on output results;
- User collaboration use cases;
- Data export.

UNIVERSITÀ DI TRENTO

References

GitHub repository of the project

https://github.com/cimil/plc-testbench

public access

Docker image of the project

https://hub.docker.com/r/cimil/plc-testbench-ui

public access

Paper presented at the IS2 2023 in Pisa

4th International Symposium on the Internet of Sounds

https://drive.google.com/file/d/1kFY9Hj-G7mWJP7U3CpPZf9TR95M5tQGV/view?usp=drive_link

restricted access

The **results** of this thesis work are **publicly available** in the form of **source code at** the **GitHub** URL mentioned in the slide **or** as a **pre-built docker image at** the indicated **DockerHub** URL.
A **paper** about the jointed work of Luca Vignati and me for the respective thesis was **presented at the 4th International Symposium on the Internet of Sounds**, held in Pisa on the 26-27th of October 2023 and will soon be available in the proceedings of the conference.

UNIVERSITÀ DI TRENTO

Prizes

During the conference **in Pisa** the software was **presented to** a **team of experts** and got a **very positive feedback**.
At the end of the conference Vignati and me had the great honor to be prized with the **“Best Demo Award”**.

Thank you so much for your attention.
Now I am at your disposal in case there are any **questions**.

UNIVERSITÀ DI TRENTO

Conclusions

PLC Testbench Native interaction	Web GUI
- limited and raw visual output - no output integration - programming-level interaction - installation complexity	- sophisticated visual output - highly integrated output - graphical interaction - installation ease

Finally this slide summarizes the **major achievements** of this thesis work by highlighting the **most critical limitations** of the native PLC Testbench's interface and how they were **addressed and overcome** in the web GUI.
For example:

- **limited and raw output** has been **replaced by** a **sophisticated dashboard** where **information** is **highly integrated**;
- **interaction mode** has been turned **from programming level into graphical**;
- **installation complexity** has been completely **hidden**.

UNIVERSITÀ DI TRENTO

Acknowledgements

Thanks to

Prof. Luca Turchet
Ing. Luca Vignati

for the invaluable feedback and support provided