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** morning / **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 that, being complementary to a Ph.D research carried out by Luca Vignati, it had an **immediate applicability** and the **topic** was totally **new** to me **and** therefore very **challenging**.

UNIVERSITÀ DI TRENTO

# Introduction

1. **Context**
PLC Testbench, a tool for the comparison of Packet Loss Concealing algorithms

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

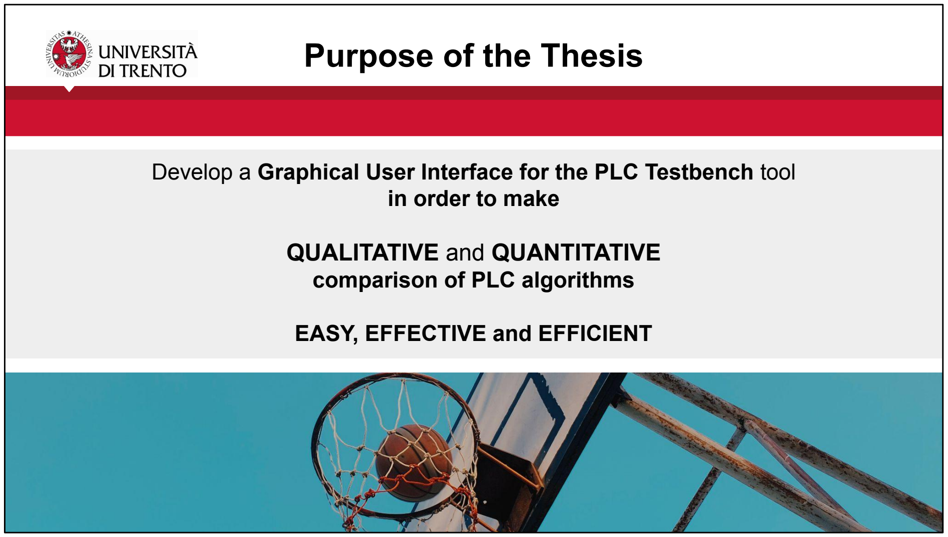
3. **Solution**
Development of a graphical user interface

The **context** in which the idea of this thesis was born is the **PLC Testbench**, which is a tool to compare the effectiveness of different Packet-Loss-Concealment algorithms.
**PLC algorithms** try to **make packet loss** in audio streams **unperceivable** by reconstructing the lost portions of the signal to **provide acceptable quality** even **on lossy connections**.

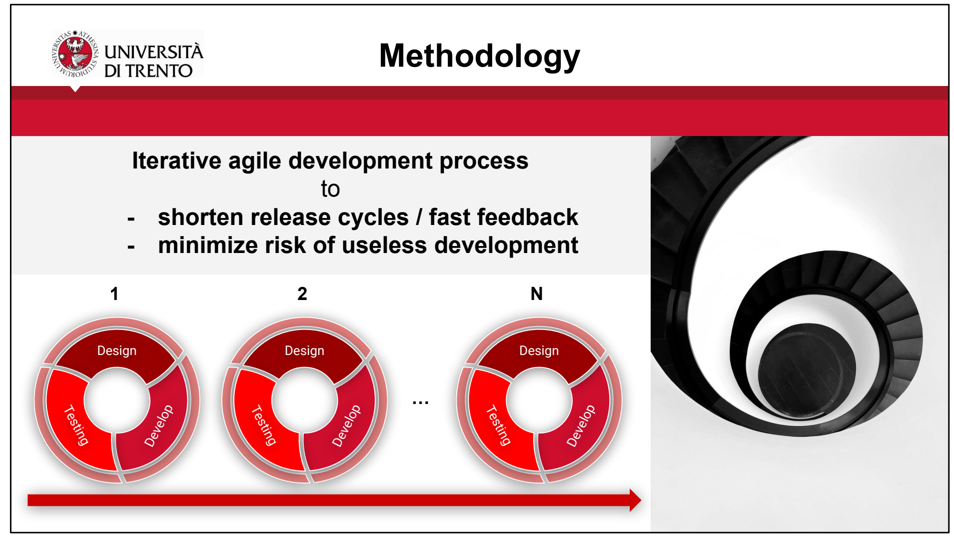
The **biggest problems** with the PLC Testbench were that:

- the only **way to interact with the tool** was **by** directly **editing** and executing the **code** in an IDE;
- the **analysis** of the outputs was a bit **cumbersome and inefficient** because the output **information** was **not integrated**.

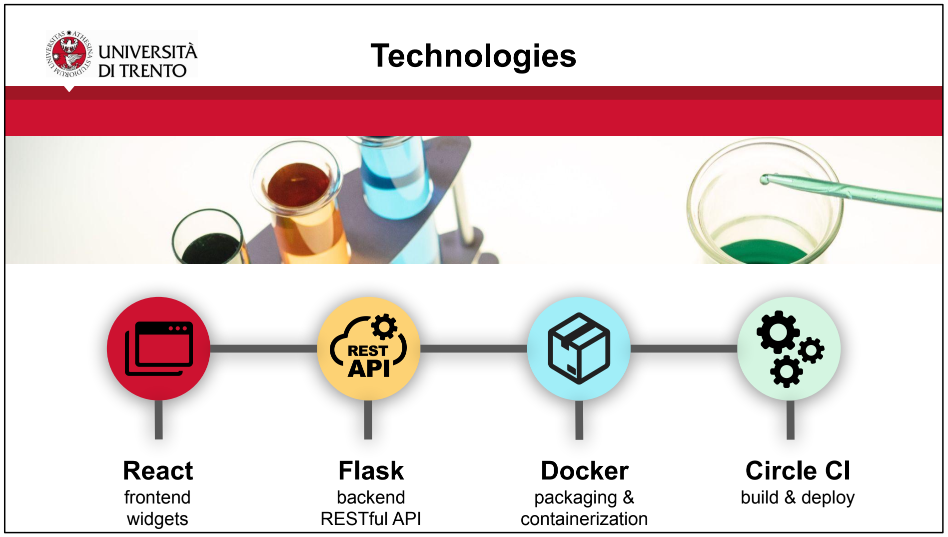
The development of a **Graphical User Interface** was seen **as a solution** to these problems.



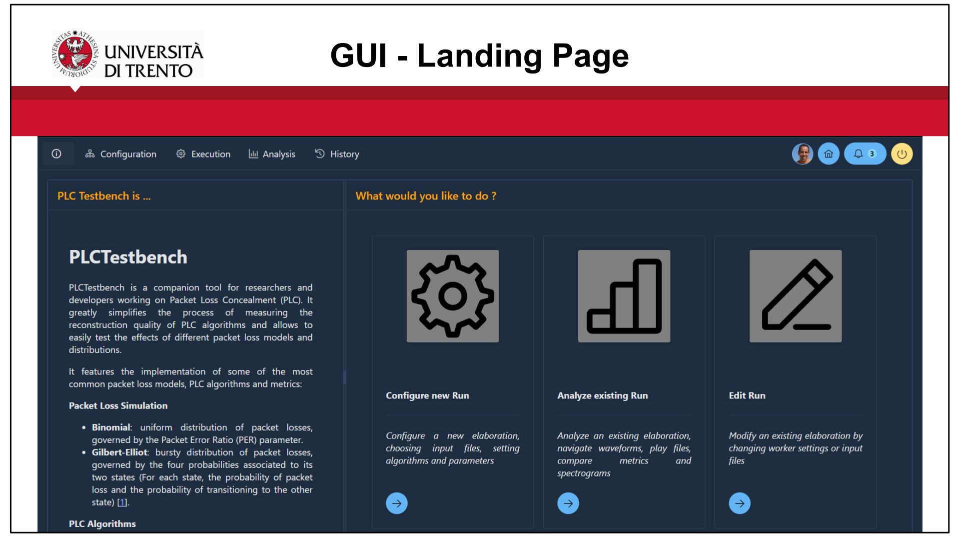

The **purpose** of this thesis work was therefore **developing a GUI** for the PLC Testbench to support the qualitative and quantitative comparison of PLC algorithms by **making the interaction** with the tool **easy**, **effective**, and **efficient**.
**Qualitative comparison** mainly consists in visually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




From a methodological perspective, it was decided to adopt an **iterative agile development process based on Kanban** because of its **simplicity** and **flexibility**.
The process essentially consisted of **short cycles of design, develop and testing** phases.
The **limited duration of the iterations** allowed keeping the focus on **small and clear objectives** and getting **fast feedback**, thus **minimizing** the risk of wasting time developing **useless functions**.



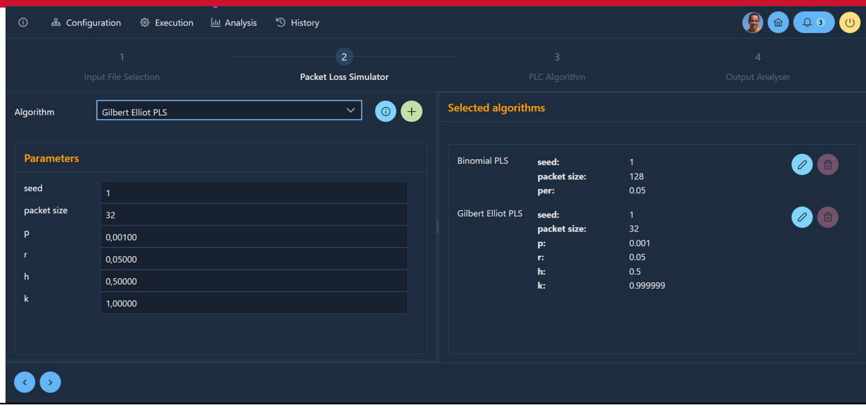

From a technological perspective it was decided to **implement** the PLC Testbench's GUI **through a Web application**, because of the **advantages** offered in terms of **ease of distribution**, **scalability** and **accessibility**.
From an architectural point of view the web application was split into **2 layers**: a **frontend** developed in JavaScript and based on React framework, and a **backend**, developed in Python with the help of the Flask framework.
**Bundling and distribution** were addressed **by containerizing** the application **as a Docker image**, while for **build and deploy** I leveraged the **pipelines as code** solution offered by Circle CI's cloud platform.




Now time has come to have a look at the application interface.
This is the **landing page** which addresses **two** main **purposes**. The first one is helping the user to **develop** a **proper mental model of the software.** To obtain this, a short **help page** about PLC-related concepts and what the application can do is displayed on the left. The second objective of this page is putting the user in condition to **start using the testbench immediately.** To achieve this, a list of the **most relevant operations** supported by the application is displayed **on the right**, with a **direct entry point** to the functions.

UNIVERSITÀ DI TRENTO

## GUI - Configuration Module

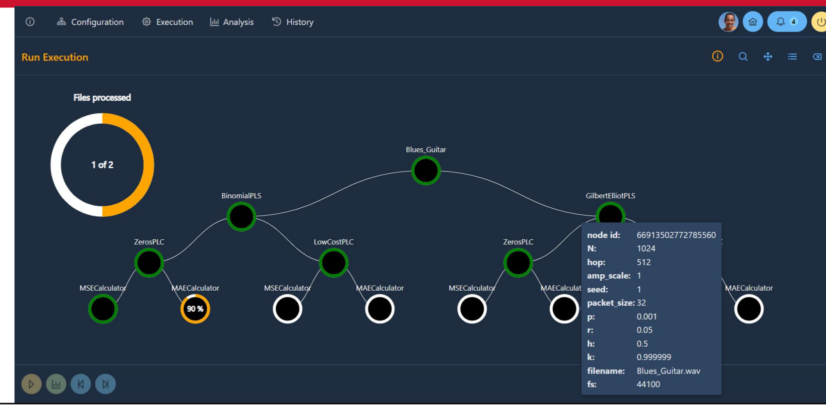



This **screen** instead is intended **to guide the user** through the collection of the input data **to configure an elaboration**. Design in this case was focused on three targets:

- **fast and effective interaction**: pursued by providing **sensibile defaults for** the **settings** and **keyboard shortcuts**;
- **clarity**: pursued by splitting the configuration process into multiple **sequential steps**, each focused on a single aspect;
- **adaptability**: achieved **by** implementing **dynamic discovery of** the available **algorithms and** their **settings**, thus supporting testbench extensions without requiring any change to the code.

UNIVERSITÀ DI TRENTO

## GUI - Execution Module




A PLC Testbench **elaboration** can be represented **as a forest of trees,** where each tree corresponds to the processing of a single input file.
Since an elaboration can in some cases take a considerable amount of time, having the **possibility to monitor progress** was **essential**.
Being the **structure** of the elaboration **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**.

UNIVERSITÀ DI TRENTO

# GUI - Analysis Module - 1

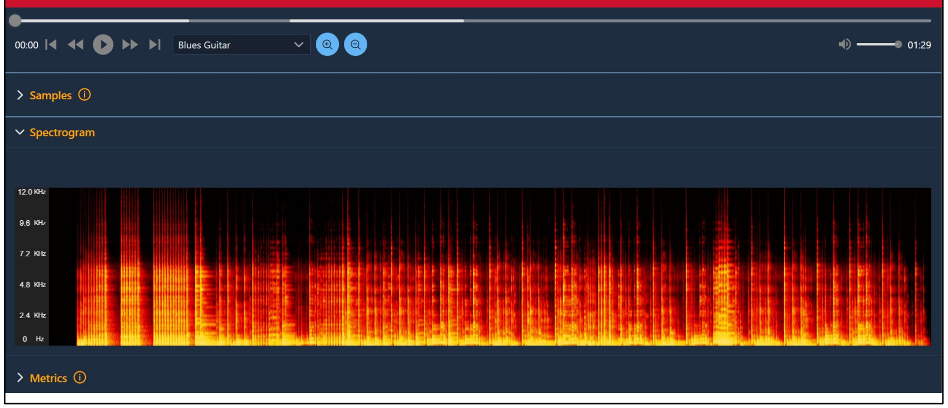

In the analysis module the **waveforms of all the versions of a** given **input file** are **displayed on the same chart**, **together with the lost packets' regions.**
Each **waveform** can be **shown or hidden** by activating or deactivating the corresponding checkbox in the selected audio files dropdown.
Each **audio file** can be **played** by the playback controls and bar below the waveforms chart, **to evaluate** the **perceived quality of the reconstruction.**
By dragging the mouse pointer over the chart it is **possible to zoom-in** any portion of the file. The zoom operation can be repeated **until the desired level of detail is reached**.

UNIVERSITÀ DI TRENTO

# GUI - Analysis Module - 2

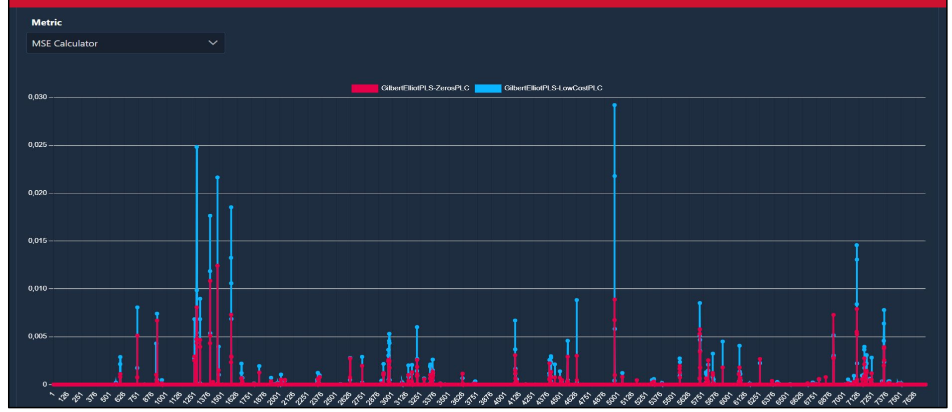

When clicking on a lost packets region in the "Waveform" view, the **detailed waveforms** of all the audio signal's reconstructions are displayed **in the "Samples" view** for a **slightly wider area surrounding the lost packets.** Each **waveform can be shown or hidden** by **clicking on** the corresponding item in the **legend**.
**Zoom-in and zoom-out** are supported by dragging the handles in the bar below the chart. **At maximum zoom level single audio signal's samples can be discriminated.**
The more the original and the reconstructed **signals** are **overlappable**, the more the **reconstruction** can be considered **accurate**.

## GUI - Analysis Module - 3

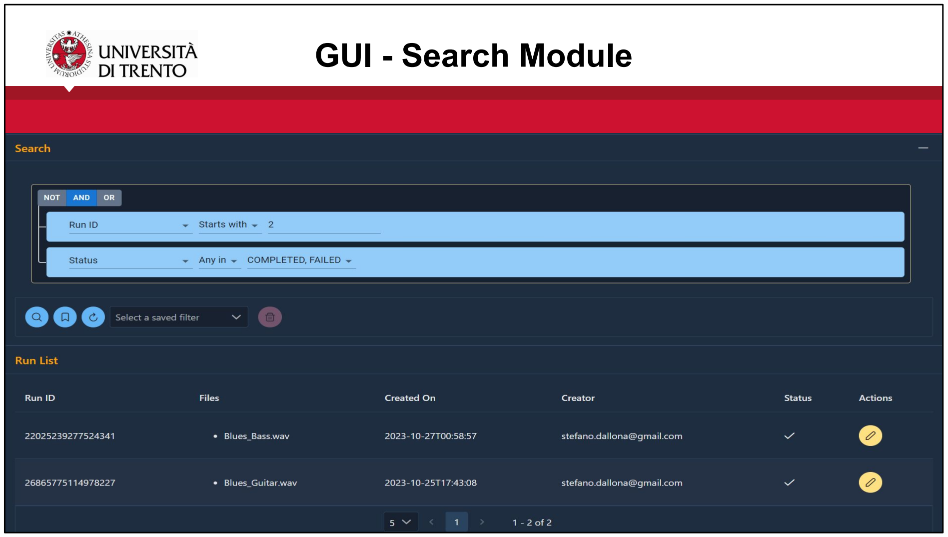



For each audio file a **spectrograms** can be displayed, representing the **composition of the audio signal over time as a color map**, where **brighter colors** correspond to **greater intensity of the corresponding frequencies**.

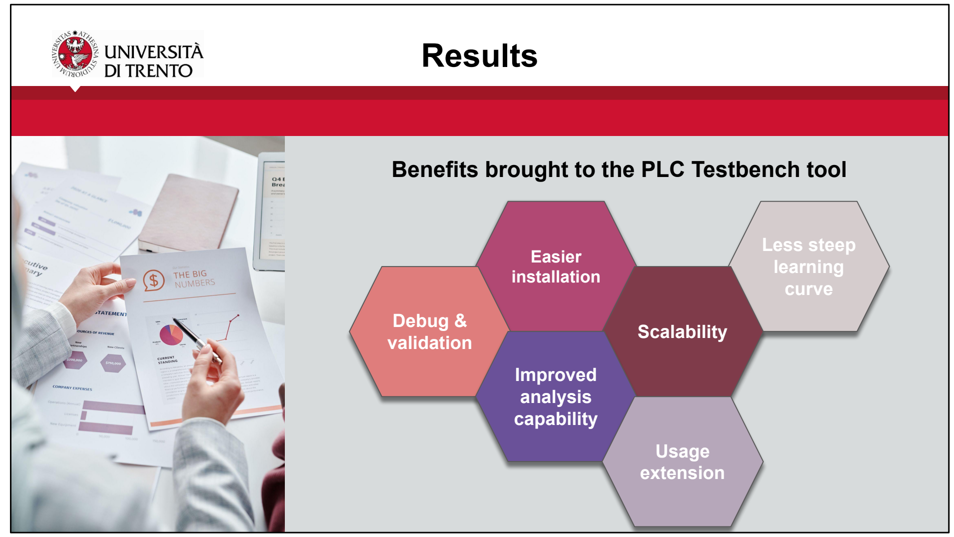
## GUI - Analysis Module - 4




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.

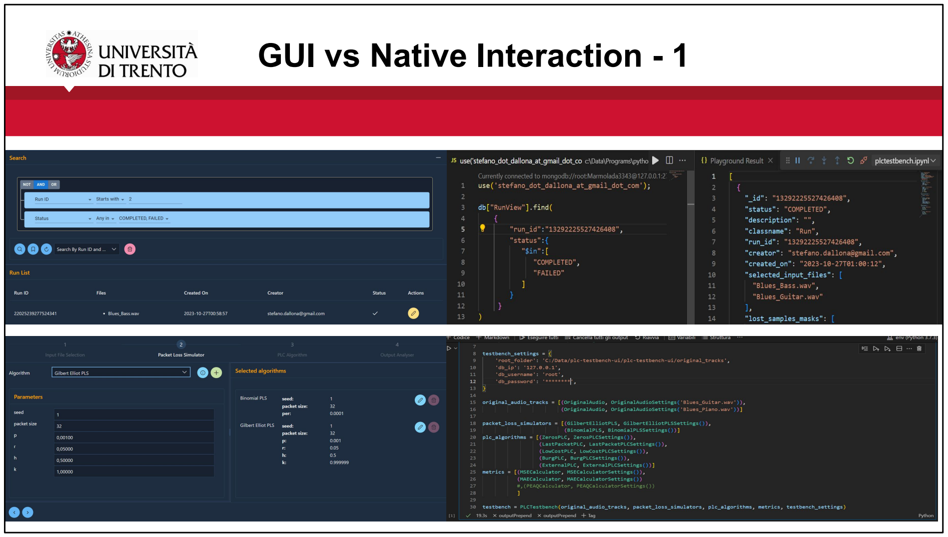


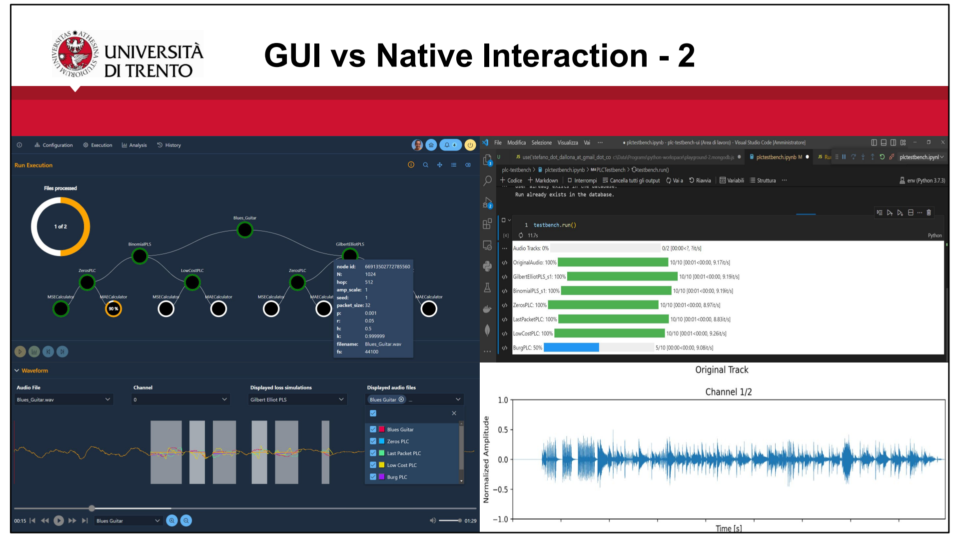

The search module allows the user to **navigate through the list of the elaborations** or to **build**, **save** and **re-execute** specific **queries**. Queries can be built visually by **combining** multiple **conditions using logical operators**. Each **condition** can be **based on any field** of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




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 hiding the **complexity in** the **build** process **of the docker image**;
- the **application** has been made **more scalable by** making **distributed deployment** possible;
- the tool **can** now **be used** also **by users with no expertise in Python programming.**




This slide shows a visual **comparison of** how some **operations** are handled **in the web GUI versus** how they are carried out through **the native** testbench **interface**. On the left we can see how the **GUI** supports **visual**ly building a queries to find specific elaborations or configuring new ones. On the right, in the **native interaction** the same operations have to be performed **at programming level**.

Here the **same comparison** Is displayed **for progress monitoring and result analysis use cases.**
Again the web **GUI** provides a more convenient and effective interaction by presenting **output information** in a **more detailed and integrated** way. For exanple only in the GUI the **hierarchical structure of the elaboration** can be recognized and the **lost packet regions** are **overlapped to waveforms**.

UNIVERSITÀ DI TRENTO

## Future Work

**A few ideas**

- *Extensive validation with users (*)*
- *Support for additionals audio formats*
- *Exposing logs*
- *Search functions on output results*
- *UI Themes*
- *Support for additional languages*
- *User collaboration use cases*
- *Additional authentication & authorization methods*
- *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**. In this slide I tried to provide some indications on **possible future enhancement areas**, like:

- Extensive validation with users;
- Support for additionals audio formats;
- Exposing logs;
- Search functions on output results;
- Management of UI Themes;
- Support for additional languages;
- User collaboration use cases;
- Additional authentication & authorization methods;
- Data export.

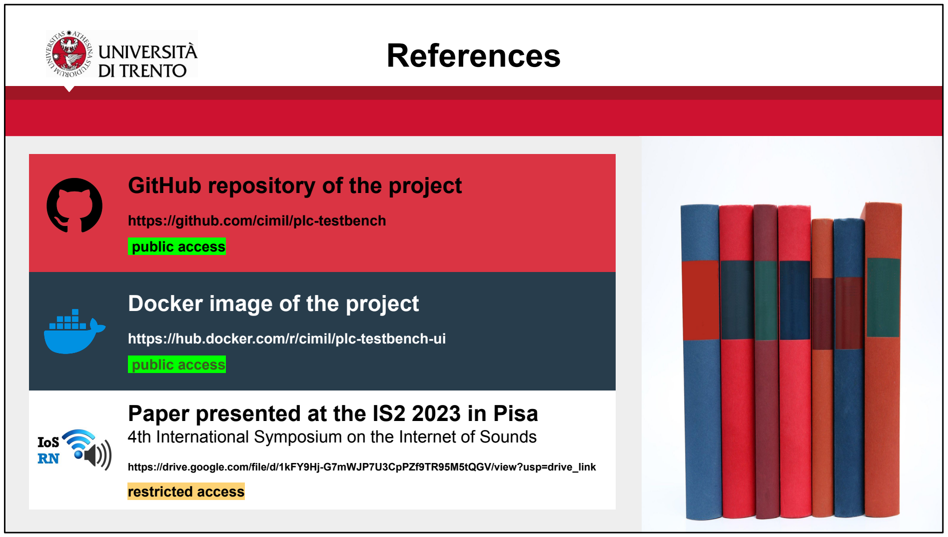
UNIVERSITÀ DI TRENTO

## Conclusions

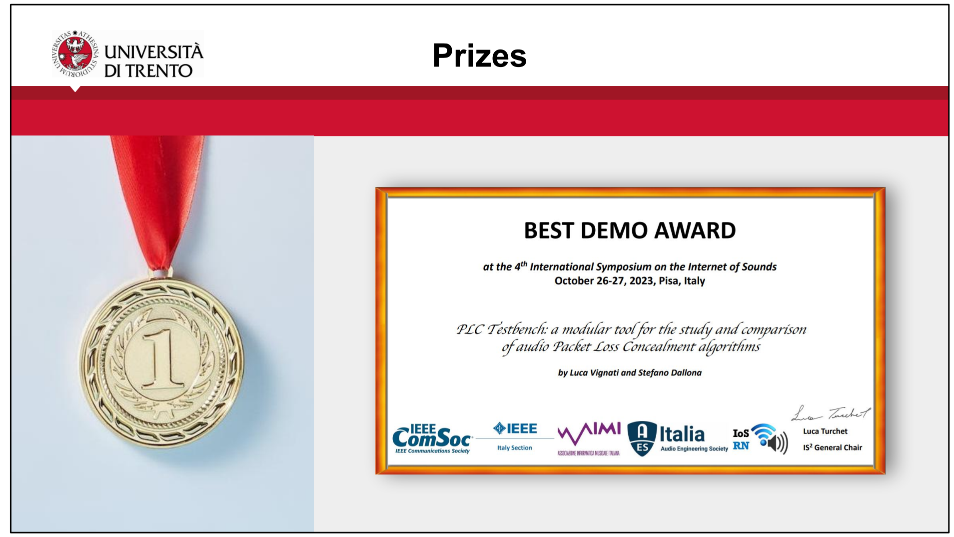
| PLC Testbench Native interaction | Web GUI |
|---|---|
| - limited and raw visual output<br>- no output integration<br>- programming-level interaction<br>- installation complexity | - sophisticated visual output<br>- highly integrated output<br>- graphical interaction<br>- installation ease |

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;
- **from** the **programming level** the **interaction** has been turned **into graphical**;
- **installation complexity** has been completely **hidden**.




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.




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**.