ENSEA

Beyond Engineering

APLM

(**A**utomated **P**iano **L**earning **M**odule)

Project semester 8 2024-2025

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I. Reminder and brief presentation of the project

Figure 1: Representation of the project generated by IA

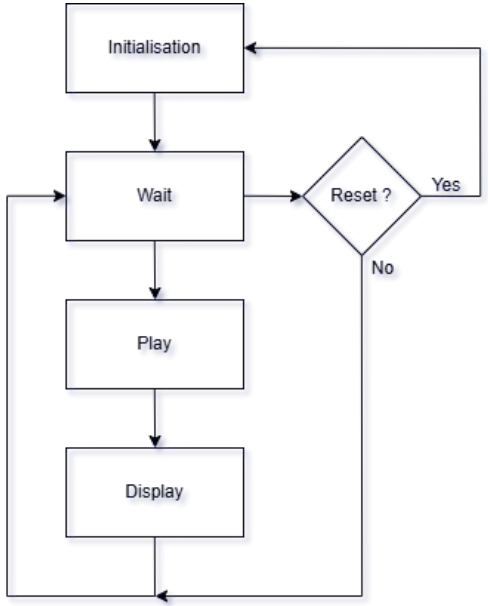

Figure 2: Project function diagram

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I. Reminder and brief presentation of the project

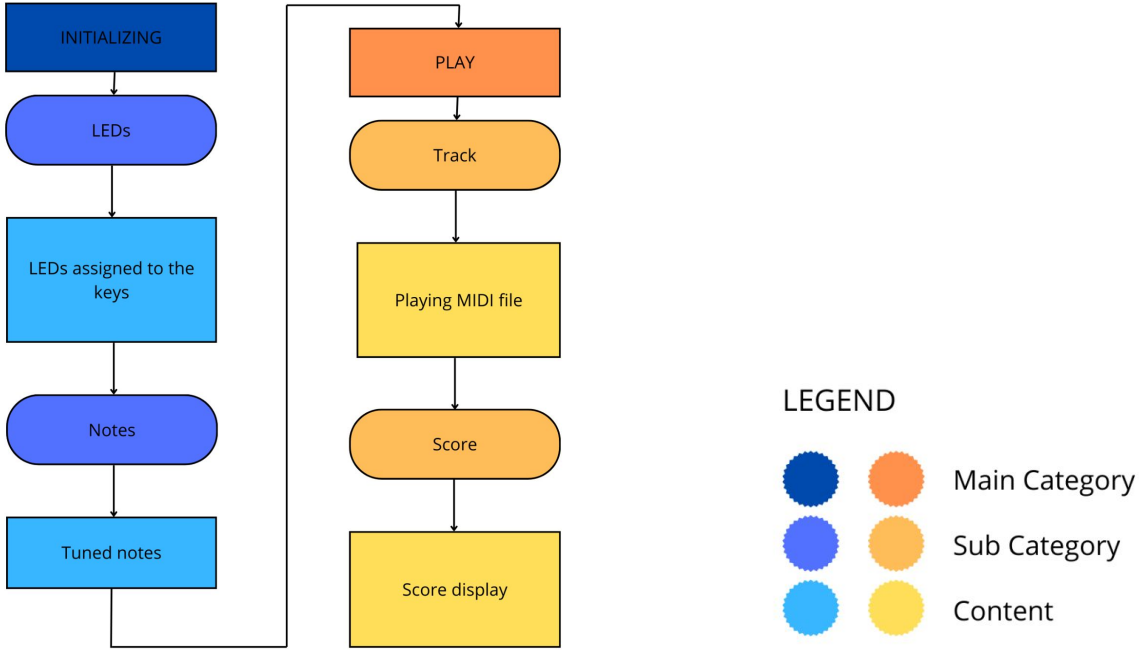

Figure 3: Initializing and Play

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II. Demonstration

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II. Demonstration

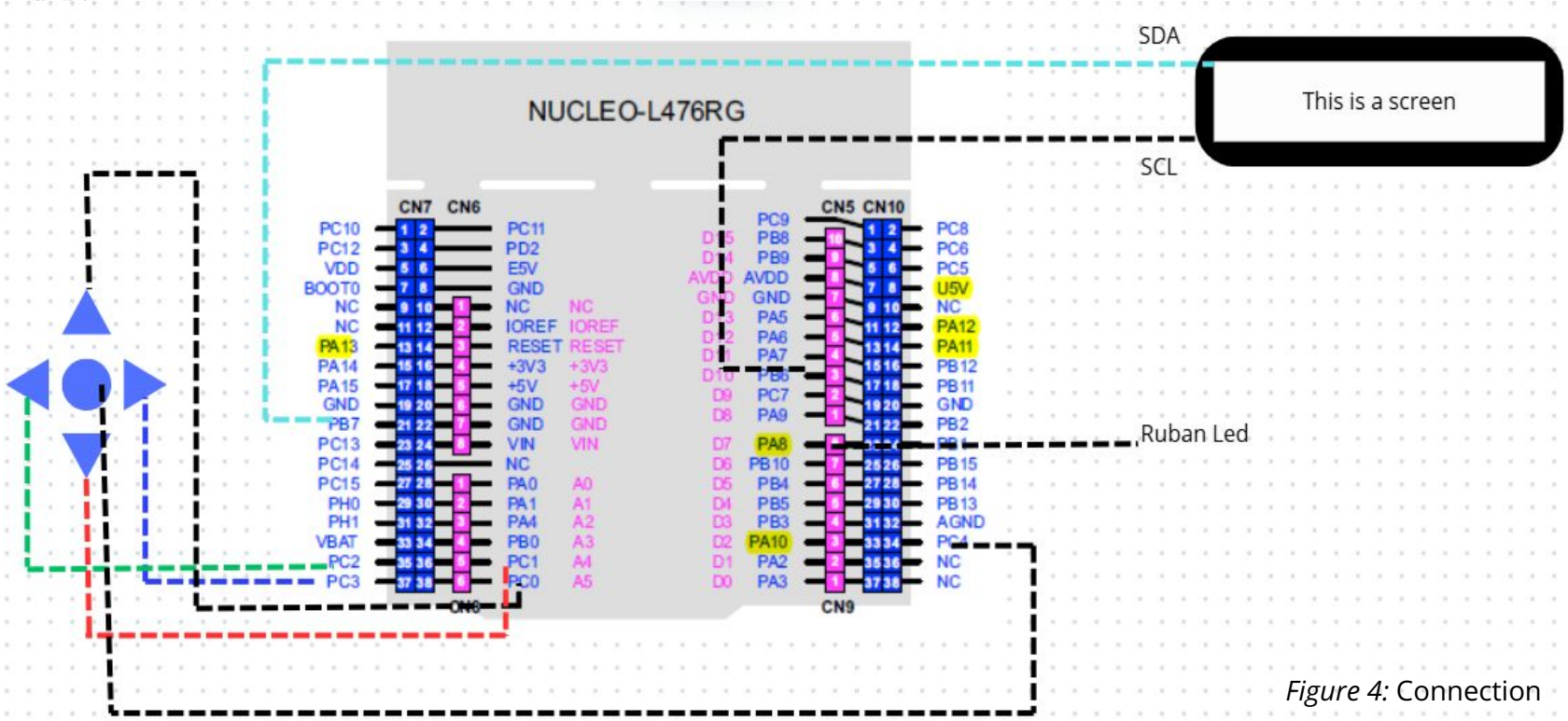

Figure 4: Connection

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1) Initialization

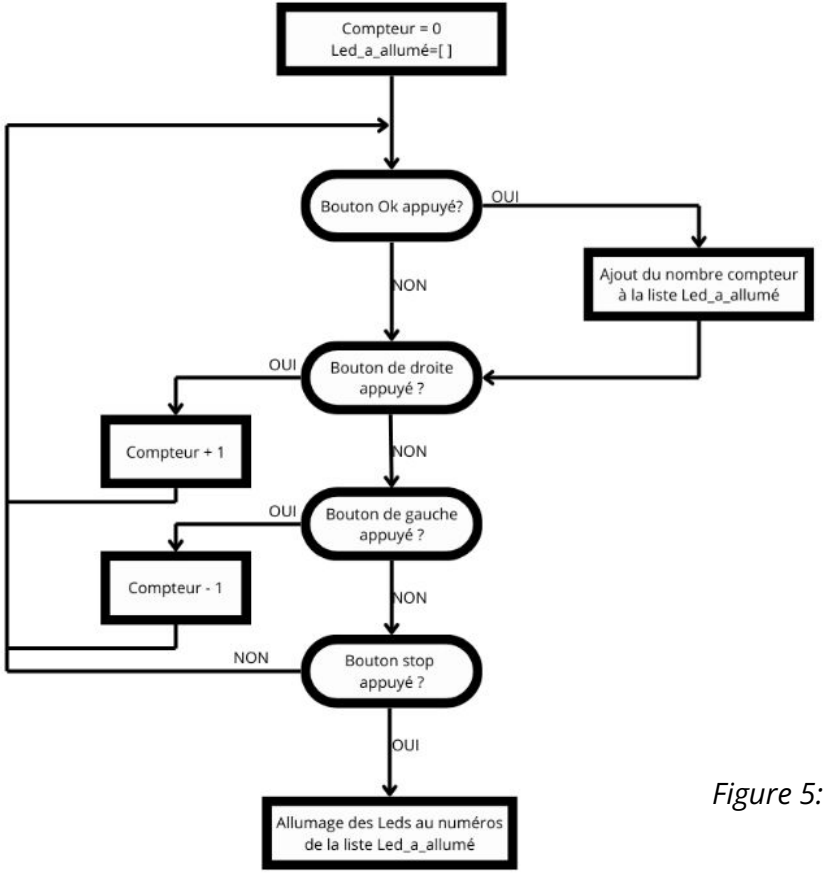

Figure 5: Decision diagram of Led assign

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2) Menu

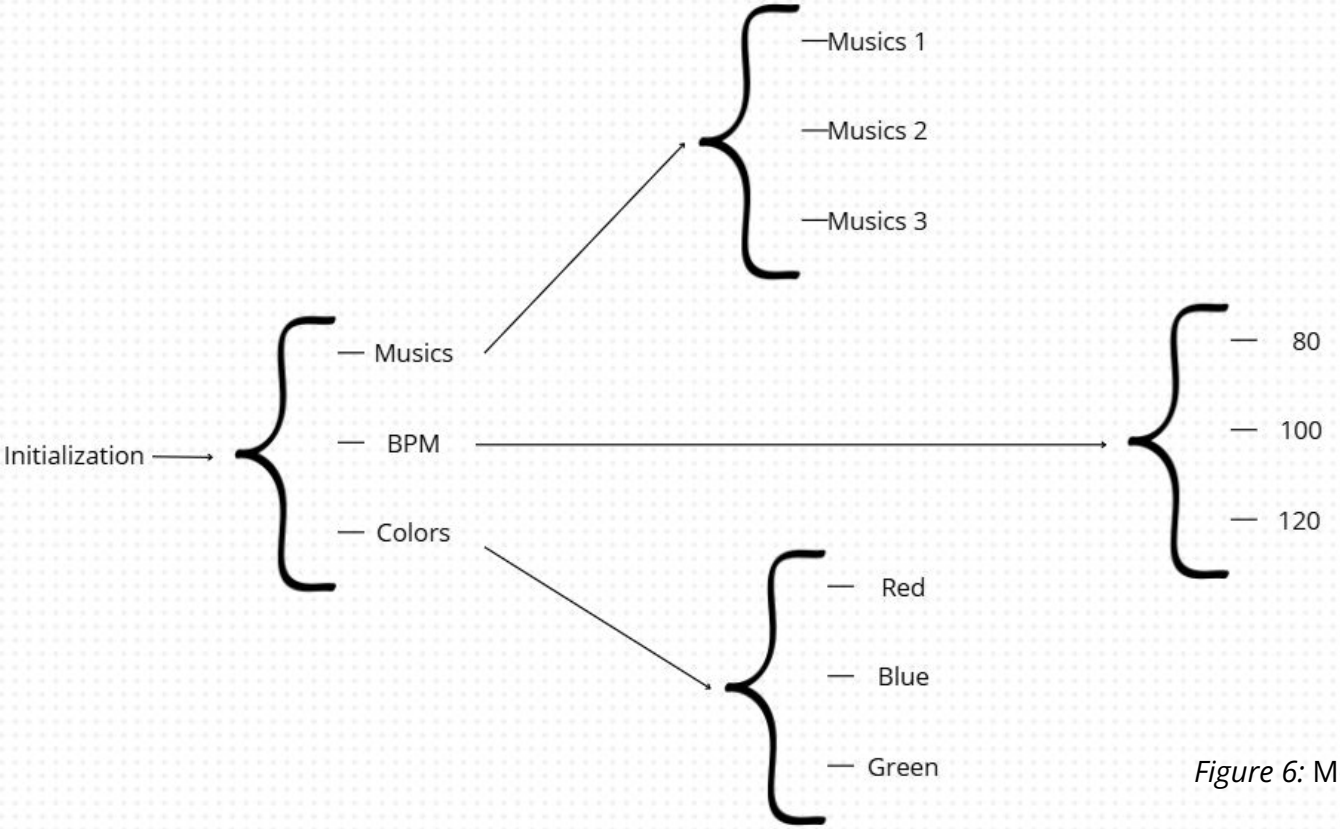

Figure 6: Menu navigation

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3) Possible Ameliorations

- Do the test for an entire piano and not just an octave
- Store more MIDI file in a SD card to play different music
- Increase the number of floors
- Complete the User Interface and functionality (Colors,BPM,...)
- Correct the initialization list with the real list played when there are several floors

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III. Additional schematic and PCB Design

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III. Additional schematic and PCB Design

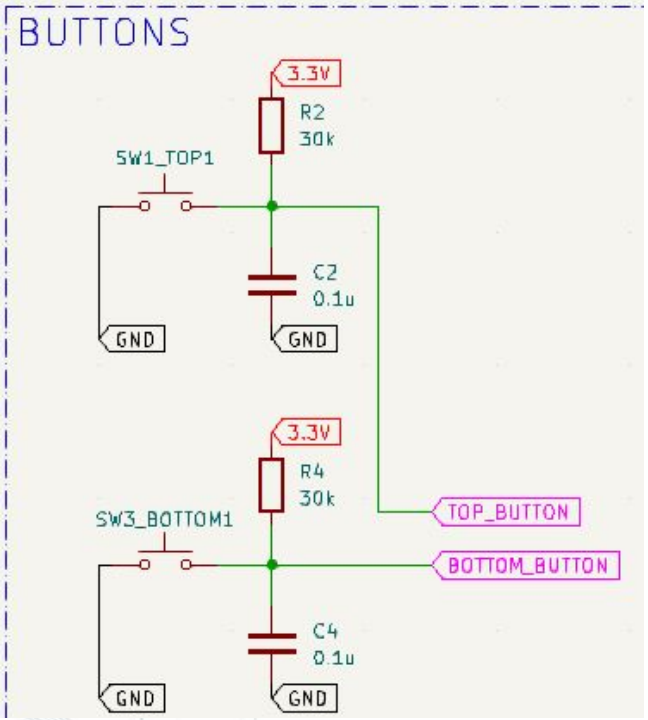


Figure 7: Buttons schematic

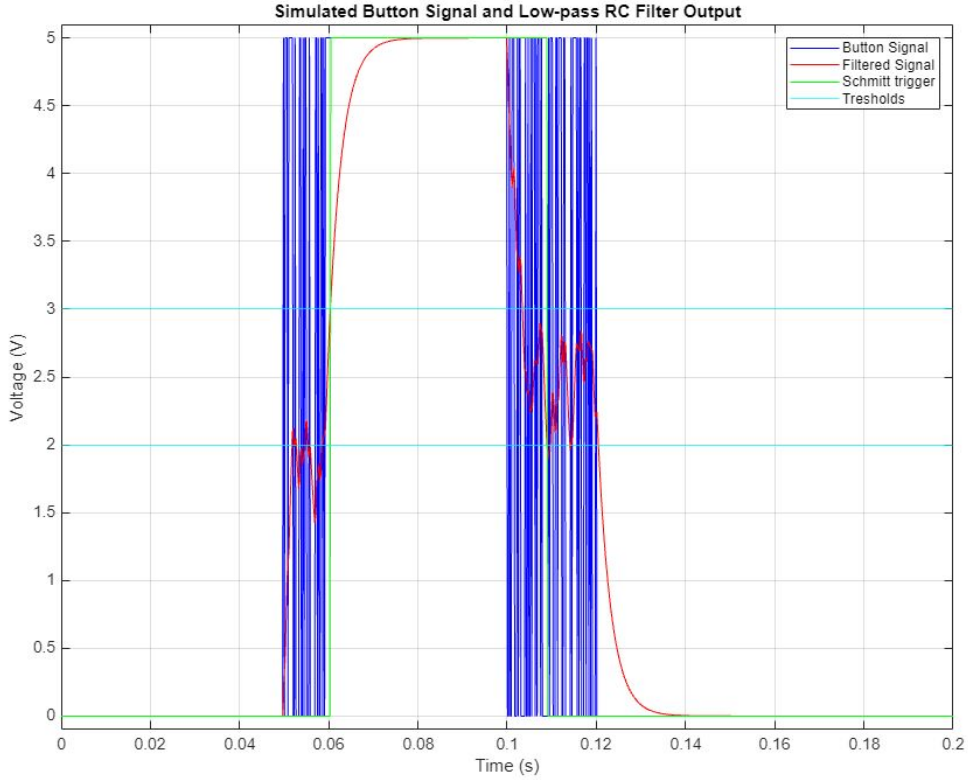
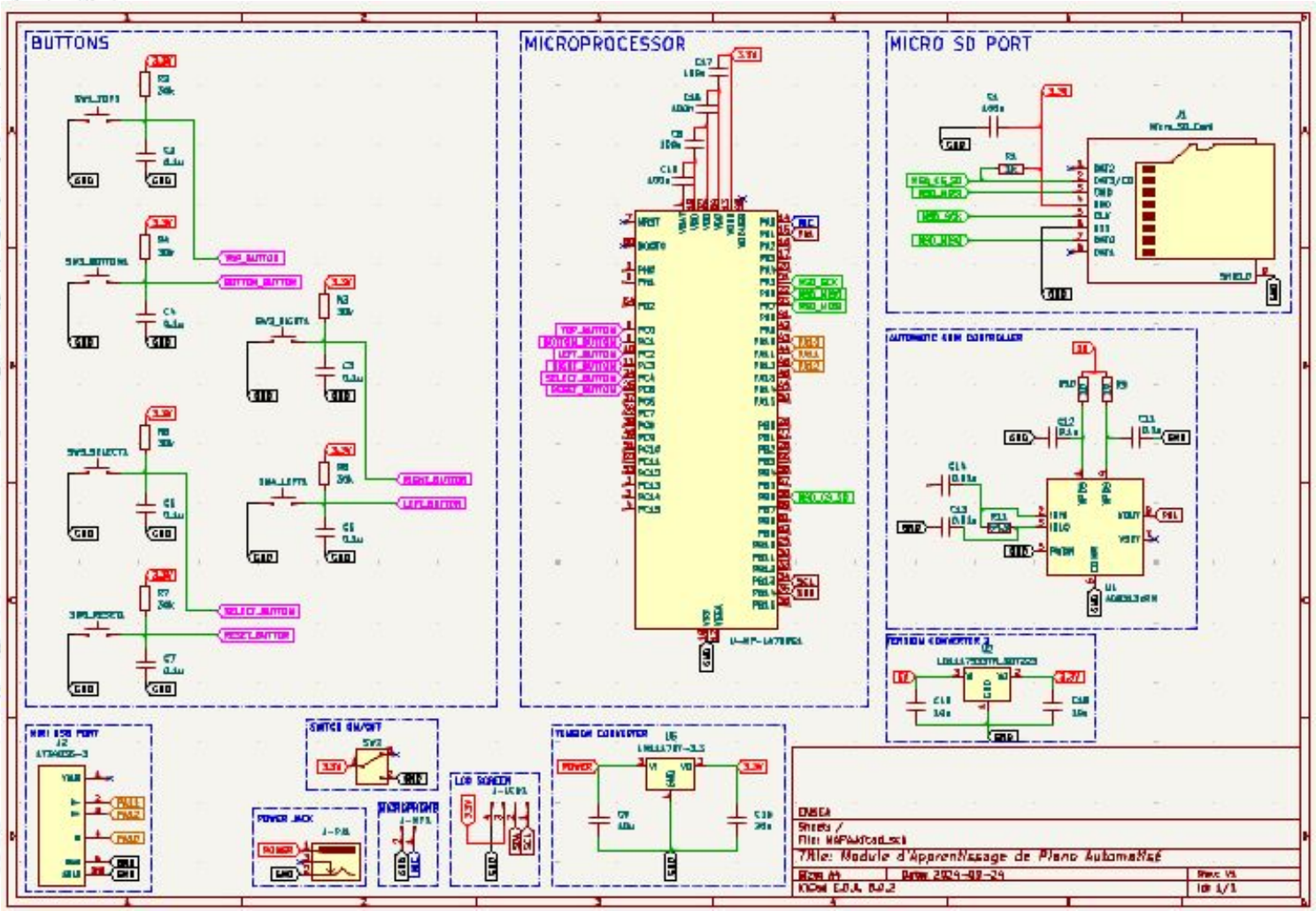


Figure 8: Button simulation



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III. Additional schematic and PCB Design

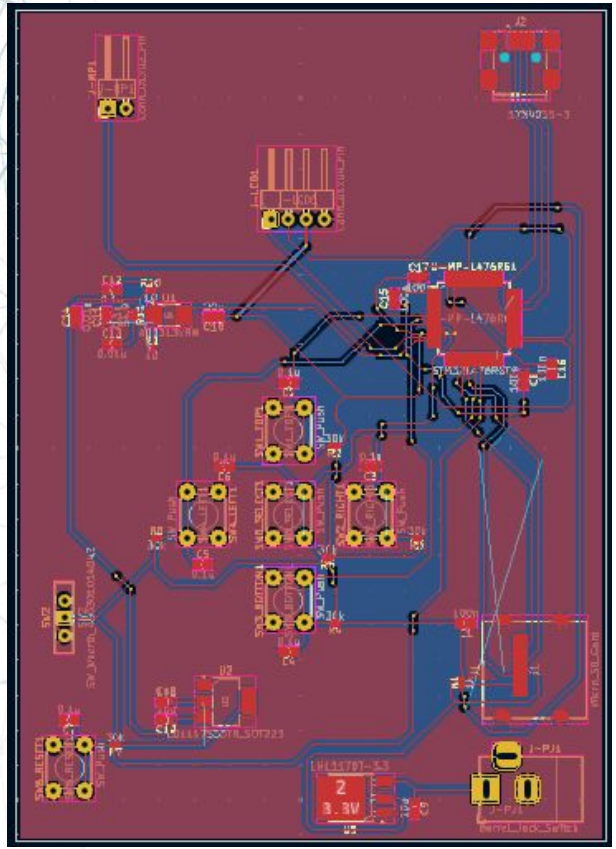

Figure 9: APLM PCB

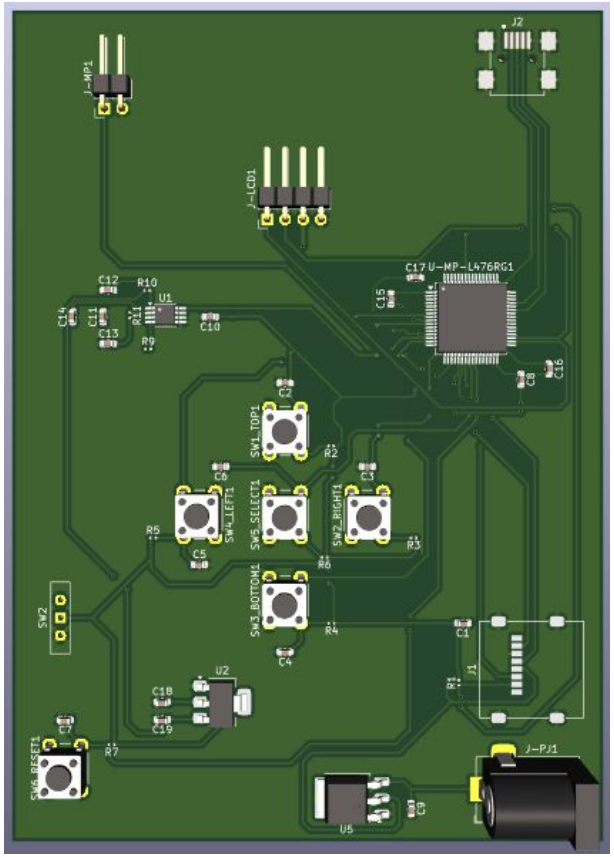

Figure 10: APLM 3D view

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III. Additional schematic and PCB Design

What's left to do as of today :

- Fix the issue with certain components on the PCB
- Print the PCB
- Solder the components onto the board

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IV. Digital audio signal processing

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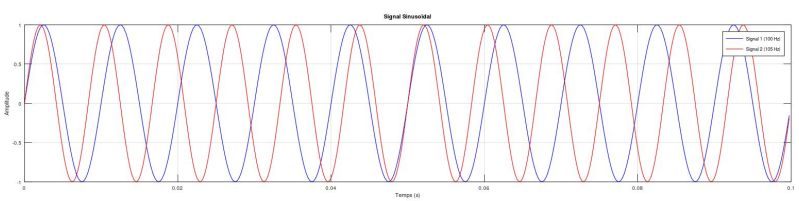
IV. Digital audio signal processing



$$S_{Tn} = \left(1 - \frac{|f_{OnTH} - f_{OnMS}|}{f_{OnTH}}\right) * \frac{100}{100} \quad \Rightarrow \quad S_{Final} = \frac{1}{N_0} * \sum_{i=1}^{N_0} S_{Ti}$$

T_N : Le N-ième temps joué

N_0 : le nombre de temps du morceau

Figure 11: Method for evaluating the user score

Figure 12: Useful libraries for the project

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V. Digital audio signal processing

Solutions

Solution	Conditions d'estimation des temps	Temps d'acquisition (ms)	Temps de calcul FFT (ms)	Total (ms)	Impact sur CPU STM32	Complexité d'implémentation	Prix supplémentaire	Conclusion
STM32L476RG (CMSIS-DSP)	Cortex-M4 à 80 MHz avec FPU Deux FFT exécutées séquentiellement avec CMSIS-DSP	3	4	7	Fort	Nécessite l'implémentation d'un code à partir de la bibliothèque CMSIS qui est difficile d'utilisation avec un temps de développement supplémentaire plus long.	0,00 €	Sélectionné
X-NUCLEO-IKS02A1	Temps d'acquisition via I²C/SPI estimé à ~1-2 ms Calcul FFT effectué sur STM32 avec CMSIS-DSP	1-2	4-6	5-8	Moyen	Ne nécessite pas de code complexe et trop de temps de développement supplémentaire.	29,39 €	Recalé
ADS1299	Temps d'acquisition via SPI à 16 S/S Calcul FFT effectué sur STM32 avec CMSIS-DSP	0,2	3,2-4,2	3,4-4,4	Moyen	Ne nécessite pas de code complexe et trop de temps de développement supplémentaire.	29,87 €	Recalé
AD7768	Temps d'acquisition via SPI ou LVDS (256 kS/S) Calcul FFT réalisé à un FPGA ou un DSP dédié	0,05	~0,5 (via FPGA/DSP)	0,55	Faible	Ne nécessite pas de code complexe et trop de temps de développement supplémentaire.	20,96 €	Recalé

Figure 13: Options in numbers

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Paradigm shift

When initialising, record every FFT of every note on the piano!

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Advantages:

- Frees up the processor for a real-time FFT
- Simplifies programming (no need to search for a maximum, cross-correlation of theoretical and measured signals)
- Gives the processor extra room to manoeuvre

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Physical simulation of the new process

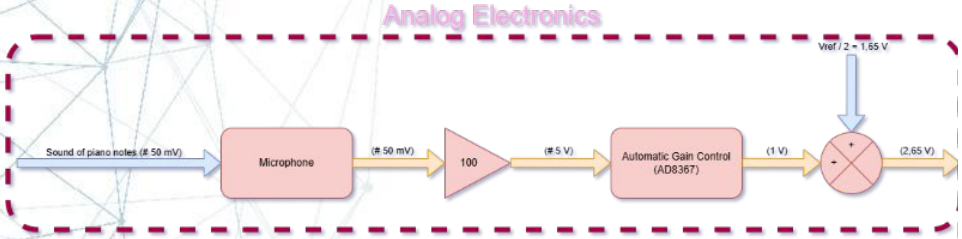

Figure 14: Function diagram of the DSP section

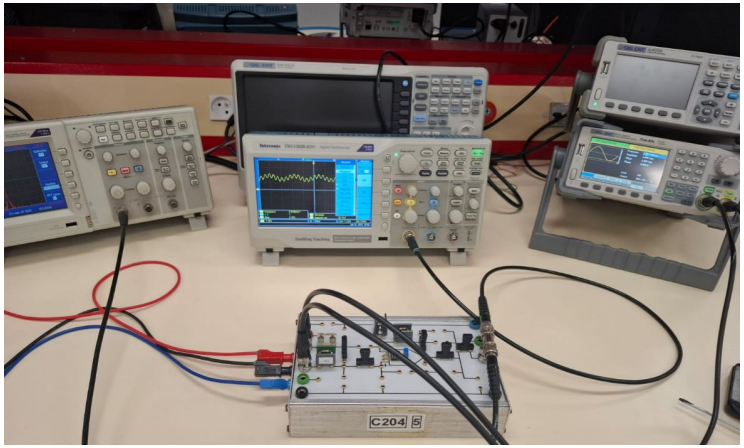

Figure 15: Representative electronic circuit for the new process

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Physical simulation of the new process

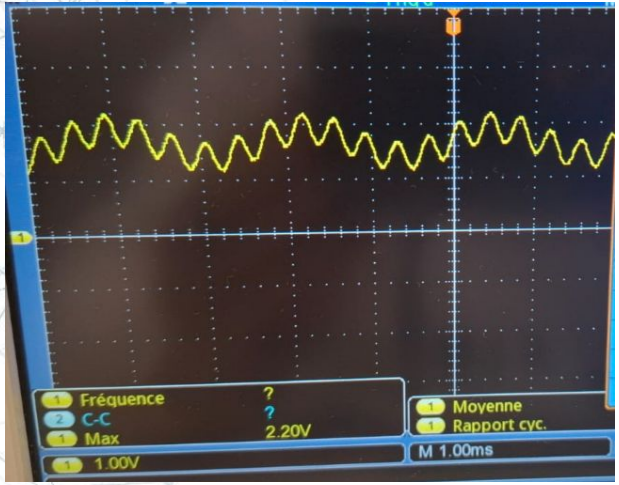

Figure 16: Sum of signals

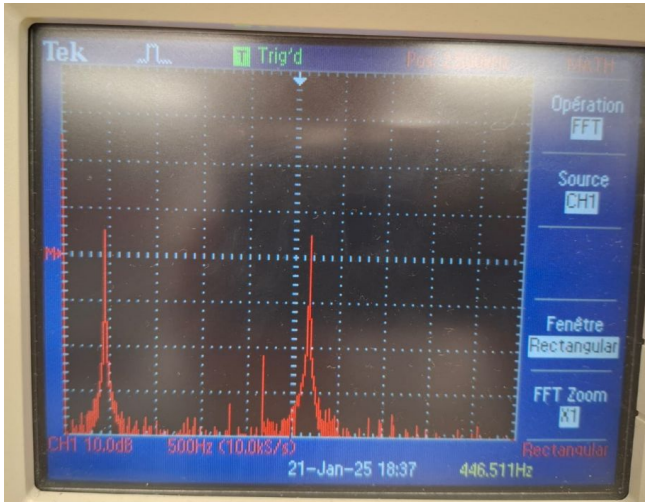

Figure 17: FFT of the sum

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Introduction of white noise

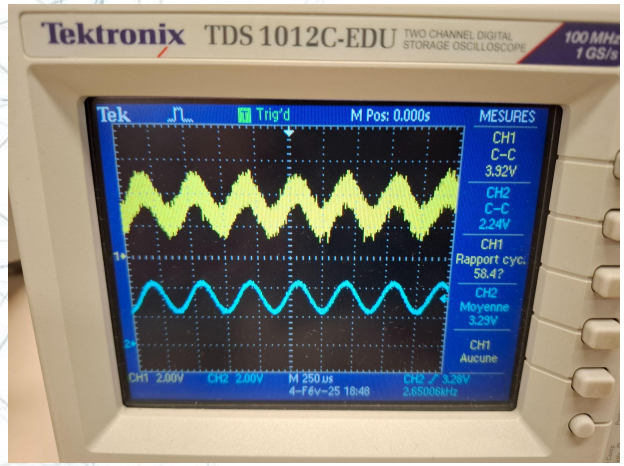

Figure 18: Noisy and filtered signal

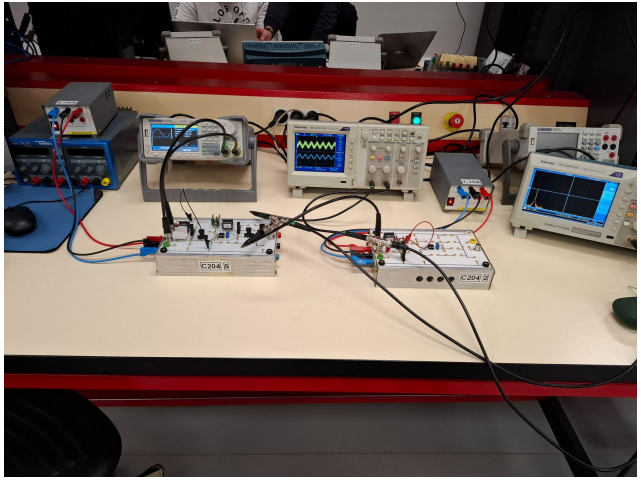

Figure 19: Electrical installation

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Averaging filter

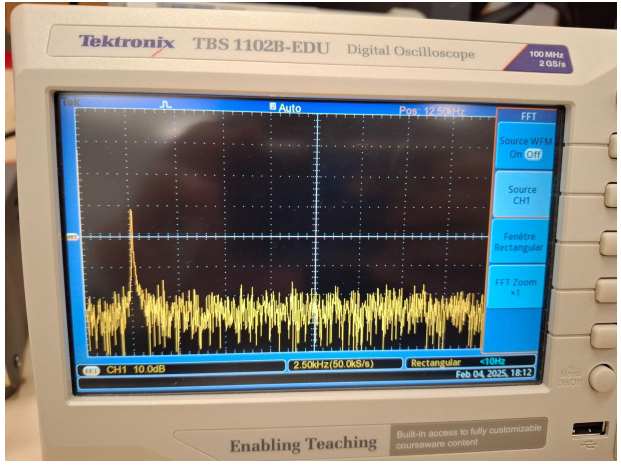

Figure 20: Filtered FFT

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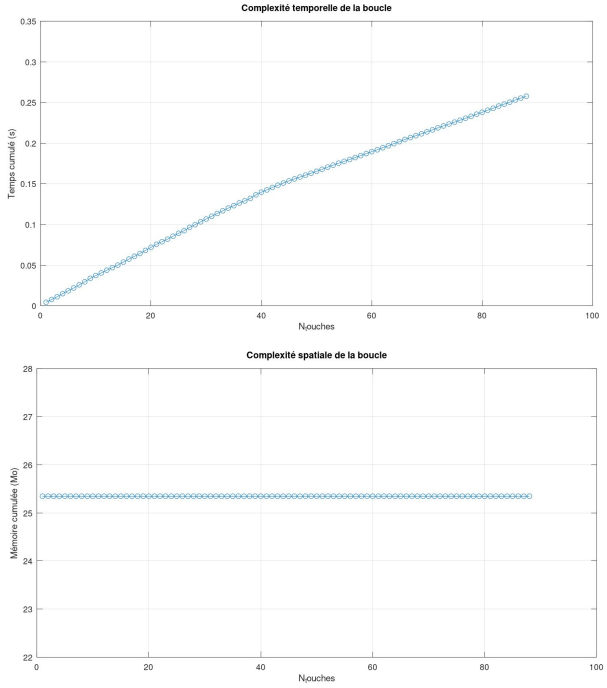

Figure 21: Temporal and spatial complexity for the greedy algorithm

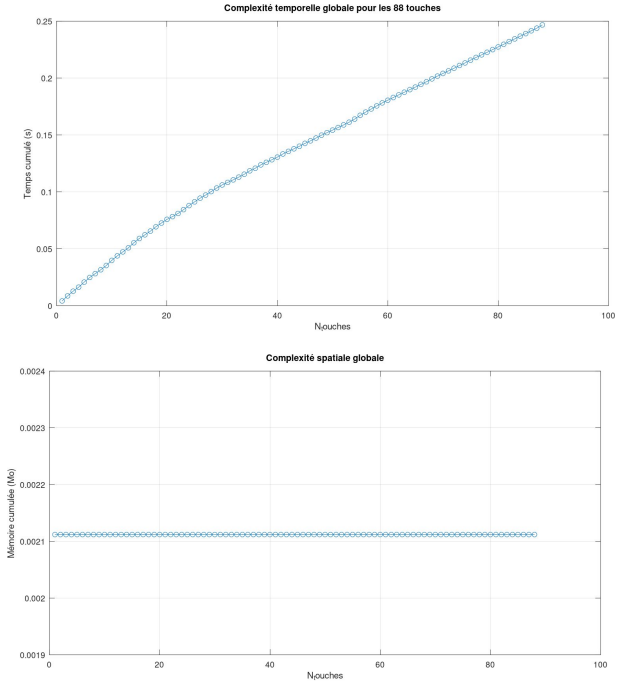

Figure 22: Time and space complexity for the finer algorithm

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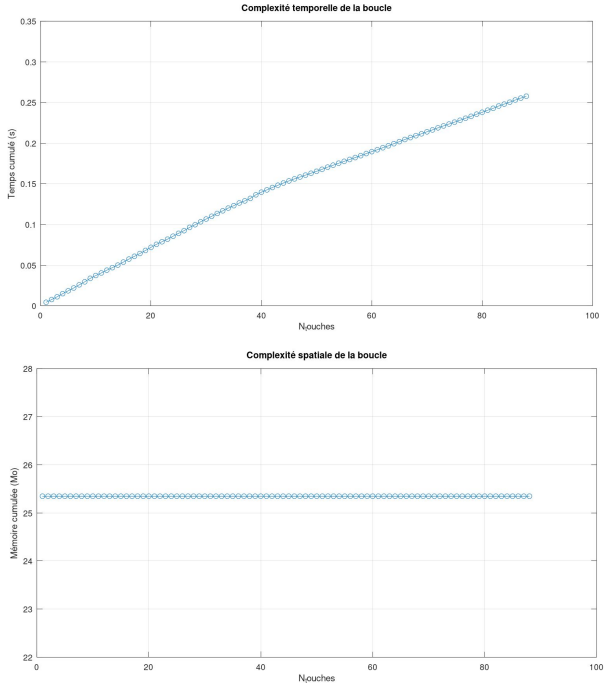

Figure 23: Temporal and spatial complexity for the greedy algorithm

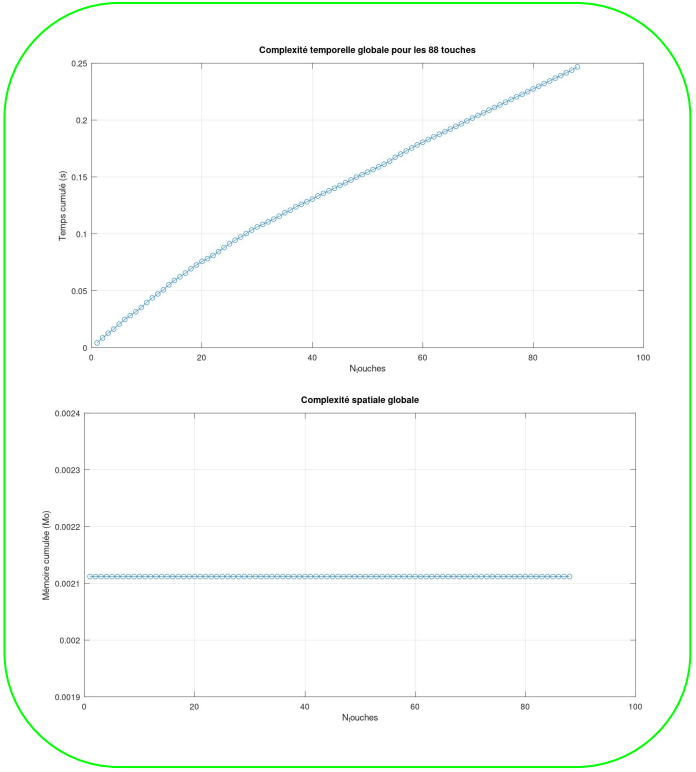

Figure 24: Time and space complexity for the finer algorithm

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Thank you for your time and attention!