Group project

Music therapy through hand gesture recognition

Rehabilitation Engineering OENG1137 (2023)

Introduction:

The clinical application of music to improve patients' quality of life is defined as music therapy. Music therapists use various methods such as songwriting, singing, instrument playing and listing. Evidence-based use of music has led to improvements in cognitive, motor and emotional skills, among many other improvements. Indeed, music therapy has been used as part of rehabilitation strategies for patients with neuromuscular disorders such as Parkinson disease, stroke and muscular dystrophy.

Whilst we know that music therapy is a useful tool to support the needs of patients with neuromuscular disorders, the limited movement ability of patients has limited the reach of this important tool. To address this, new technologies are needed to widen the scope and reach of music therapy.

There has been a long history of using hand gesture recognition for interaction between neuromuscular disorder patients and the outside world. This project focuses on the development of a system, which enables patients to play music through hand gestures. It is hoped that your device will lead to the rehabilitation of lost muscle function over the long term.

Objective:

Develop a MATLAB framework capable of playing musical tones, controlled by EMG signal generated by voluntary hand gestures. You will need to generate sound through your computer and change the pitch (frequency) based on changes in hand gestures.

Logistics:

Team size: two to three students per team.

Teams: self-selected – contact me if you don’t have a team.

Sessions: as well as the timetabled lab sessions, you may find it necessary to perform parts of the activity in your own time.

Resources:

1. Computer with MatLab
2. A selection of data from the putEMG databased. The lab demonstrator will assign the data to each of the teams. Make sure you work on the data assigned to your team.

Assessment:

- Due date – Sunday, 7th of May. Check on Canvas for updated due date.
- Total Mark: 100 points. This will be 35% of your final mark for this course.
- See the evaluation criteria below and cover the points listed in the evaluation criteria.
- The video presentation can be any length. As a guide, video presentation lengths are normally around 30~40 min.
- Although not mandatory, it may be helpful to follow the general format shown in the evaluation criteria.
- Make sure you highlight your technical achievements as well as your knowledge. You are assessed on both of these.
    - Show your work in action.
    - Always benchmark and evaluate results.
    - Explain what is happening and the results you are obtaining.
    - Always show AND discuss your results.

Evaluation criteria – Group project

Part 1: Development Journey: Total: 40% of the mark

#	Evaluation criteria	Skill being assessed	Not evident (0%)	Poor (5%)	Good (8%)	Excellent (10%)
1	Assessment of the challenges and evaluation of strategies at the start of the project.	Planning skills.	Not discussed	Identified and investigated relevant resources without citation.	Identified and investigated relevant resources with citations.	Identified and Investigated relevant resources with citations and performed a preliminary investigation of the dataset provided to evaluate strategies.
2	Design and development of an engineering solution.	Problem-solving skills.	Not discussed	Designed and developed an approach but failed to meet the objectives.	Designed and developed a basic approach that marginally functioned.	Designed and developed an innovative approach that addresses the requirements of the project.
3	Assessment of your solution.	Analytical skills.	Not discussed	Provided no engineering benchmarks.	Provided engineering benchmarks.	Provided engineering benchmarks and compared them to the state-of-the-art.

4	Identification of shortcomings in your solution and the broader context of work and proposing solutions for future improvements.	Continuous improvement strategy.	Not discussed	Proposed improvements without identifying evidence-based shortcomings.	Suggests evidence-based shortcomings and future improvements, but doesn't link the two.	Provided coherent and evidence-based shortcomings and future improvements.

Some suggestions

***Assessment of the challenges and evaluation strategies at the start of the project**:*

1) Why should we care about hand gestures and the use of hand gesture recognition in the context of assistive technologies?
2) Beyond EMG measurement, what are other methods for recognition of hand gestures? How do they compare to the EMG based hand gesture recognition?
3) Physiologically, what is the origin of the EMG signal?
4) General properties of the EMG signal you have been provided with? Consider:
    a. Amplitude and frequency content. What matters to your project?
    b. How good are the electrode performing - e.g Motion artefacts in the EMG signal.
    c. Location of the electrodes - Would you use all 24 electrodes or only a subset of these electrodes? If yes why and if not also why?
    d. etc.…
5) Choose an approach to generate music. Keep things simple and fun. What type of waveform would you use? Would they be a single-frequency waveform, or would they contain multiple frequencies?

Design and development of an engineering solution.

1) Define and justify your strategy - build on the outcome of "*Assessment of the challenges and evaluation of strategies at the start of the project*".
2) Show a flow diagram based on your strategy. Discuss why you choose the proposed flow diagram.

3) Define the engineering requirements of each block in the flow diagram. Make this evidence-based as much as possible. Discuss why you selected these requirements.
4) Implement the block diagram and demonstrate the system performance. Show a video of your code playing music. Talk the viewer through the implemented blocks.

Assessment of your solution.

1) Evaluate your system with reference to "*Design and development of an engineering solution*".
2) Develop a quantitative system to assess your work. For example, you can think about:
    a. How fast does your classifier detect the hang gesture?
    b. How accurate is it in predicting your intensions?
    c. How much did it cost - estimate?
    d. etc…
3) Compare aspects of your work, to other teams as well as to other published works.

Identification of shortcomings and proposing solutions for future developments.

Any good engineering system is being constantly refined. Build on "assessment of your solution" to identify areas of improvement. Suggest possible approaches for future improvements.

Part 2: Application of Digital Signal Processing Tools – 40% of the mark.

In this section, you need to present detailed aspects of the systems. If you have used any basic digital signal processing tools (e.g. Low pass filters or FFT) or advanced tools (wavelet, classifiers) highlight these. Each block (subsystem) is worth a maximum of 10%. To achieve you need to:

1) Identify a suitable subsystem: Justify a suitable subsystem – e.g. if you are using a low pass filter, you need to state why do you need it? Why you have selected it over other approaches etc.
2) Define the specific engineering subsystem requirements: Define and discuss the requirements for this subsystem. E.g. resolution of FFT or the time delay introduced by the filter and why? Make this evidence-based as much as possible.
3) Validate the subsystem performance: Test your subsystem using a computer-generated synthetic signal or known dataset and discuss the results. Show your results and discuss them. Do they address the requirement you have set?
4) Integrate the subsystem with the system: Once your subsystem is ready for us as part of the overall system, show and discuss how the subsystem is working as part of the entire system. How does it perform? How well does it work with other sub-systems? How does it work with your actual data?

Part 3: Performance – 20% of the mark.

In this section, you present the result of your system accuracy and the number of gestures you have been able to detect. The table below will be used to award the marks.

Key points:

- This is your music therapy system accuracy and not the ML accuracy. Think about how you can improve the accuracy of the system.
- The performance reported in the part 3 must be evaluated on data that has not been used for training.
- You may find yourself detecting one hand gesture with higher accuracy compared to others. Lowest accuracy means the accuracy of the hand gesture with the lowest accuracy. (e.g. if you detect HG 1 at 83%, HG 2 at 84% and HG 3 at 95%), the number to report is 83%.

Number of hand gestures detected	**Lowest accuracy**			
	Below 60%	**60% to 75%**	**75% to 84%**	**85% and higher**
5	0	10	15	20
4	0	7.5	10	15
3	0	5	7.5	10
2	0	2.5	5	7.5
1	0	1	2.5	5

max 5 hand gestures!! fist, idle, flexion… you choose

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Evaluation Chart - Group project

Team Name:

Team Members:			

Part 1: Development Journey: Total: 40% of the mark

#	Evaluation criteria	Skill being assessed	Not evident (0%)	Poor (5%)	Good (8%)	Excellent (10%)
1	Assessment of the challenges and evaluation of strategies at the start of the project.	Planning skills.				
2	Design and development of an engineering solution.	Problem-solving skills.				
3	Assessment of your solution.	Analytical skills.				
4	Identification of shortcomings and proposing solutions for future improvements.	Continues improvement strategy.				

Subtotal: ***/40***

Part 2: Application of Digital Signal Processing Tools – 40% of the mark.

#	Application of Elementary Digital Signal Processing Tools	No (0%)	Basic (1%)	Excellent (2.5%)
1	Identified a suitable subsystem			
2	Defined the subsystem requirements			
3	Validated the subsystem performance			
4	Integrated the subsystem with the system			

Subtotal: /10

#	Application of Elementary Digital Signal Processing Tools	No (0%)	Basic (1%)	Excellent (2.5%)
1	Identified a suitable subsystem			
2	Defined the subsystem requirements			
3	Validated the subsystem performance			
4	Integrated the subsystem with the system			

Subtotal: /10

#	Application of Advanced Digital Signal Processing Tools (ML)	No (0%)	Basic (1%)	Excellent (2.5%)
1	Identified a suitable subsystem			
2	Defined the subsystem requirements			
3	Validated the subsystem performance			
4	Integrated the subsystem with the system			

Subtotal: /10

#	Application of Advanced Digital Signal Processing Tools (Wavelets)	No (0%)	Basic (1%)	Excellent (2.5%)
1	Identified a suitable subsystem			
2	Defined the subsystem requirements			
3	Validated the subsystem performance			
4	Integrated the subsystem with the system			

Subtotal: /10

Part 3: Performance – 20% of the mark.

Number of hand gestures detected	**Lowest accuracy**			
	Below 60%	**61% to 74%**	**75% to 84%**	**85% and higher**
5	0	10	15	20
4	0	7.5	10	15
3	0	5	7.5	10
2	0	2.5	5	7.5
1	0	1	2.5	5