Real-time robot arm control using motor imaginary movements decoded from EEG signals

RESEARCH PRACTICE

submitted by
Juri Fedjaev

NEUROSCIENTIFIC SYSTEM THEORY
Technische Universität München

Prof. Dr Jörg Conradt

Supervisor: Dipl.-Ing. Zied Tayed
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Abstract

A short (1–3 paragraphs) summary of the work. Should state the problem, major assumptions, basic idea of solution, results. Avoid non–standard terms and acronyms. The abstract must be able to be read completely on its own, detached from any other work (e.g., in collections of paper abstracts). Don't use references in an abstract.

Contents

Chapter 1

Introduction

- Introduce the idea of the BCI
- applications of BCI for robotic control

  → importance (why robotic arm control), technical difficulties & limitations, challenges ...

Problem description:
Brain machine interface (BMI) is used to control a system through which people with motor disabilities could achieve a better quality of life by improving their interaction ability with the surrounding environment. Using BMI, patients suffering from severe motor disabilities can also control robot arm to carry out their activity of daily living by just generating control commands using their own EEG signals.

Your first chapter in the document. Introduce the problem (gently!). Try to give the reader an appreciation of the difficulty, and an idea of how you will go about it. It's like the overture of an opera: it plays on all the relevant themes.
Make sure you clearly state the vision/aims of your work, what problem you are trying to solve, and why it is important. While the introduction is the part that is read first (ignoring title and abstract) it is usually best written last (when you actually know what you have really achieved). Remember, it's the first thing that is being read, and will have a major influence on the how the reader approaches your work. If you bore them now, you've most likely lost them already. If you make outrageous claims pretend to solve the world's problems, etc, you're likely fighting an uphill battle later on. Also, make sure you pick up any threads spun in the introduction later on, to ensure that the reader thinks they get what they have been promised. Don't create an expectation that you'll deliver more than you actually do. Remember, the reader may be your marker (of a thesis) or referee (of a paper), and you don't want to annoy them.

1.1 Problem Statement

Excerpt from the description of the practical project:

> The main objective of this project is to implement the algorithm described in [1, 2] to discriminate and decode four motor imagery movements (left hand, right hand, both hand imaginary movement and rest) from EEG signals. Afterwards, the developed algorithm has to be used to control a robot arm in a real-time scenario.
> **Tasks:**
> This project requires the student to:
>
> - Implement an existing algorithm to classify four motor imaginary movements from EEG recorded signals.
> - Test and validate the developed algorithm in a real-time scenario when the user imagines one of the four actions, this imagination would be decoded with a BMI and the robotic arm executes the desired movement.
>
> **Optional task:**
>
> - Extend the work by using the implemented algorithm to classify reach and grasp imaginary movements

1.2 Related Work

This section will review existing approaches and possible solutions to the problem stated in section 1.1.

- Discuss related projects from other research groups (e.g. TU Graz virtual reality navigation using MI, ...)
- past achievements in the area of MI for BCI
- provide background information (e.g. motor imagery, motor cortex location and importance for project, local field potentials, ...)

Chapter 2

Main Part

2.1 Design of your solution

In this section the design of the proposed solution will be , i.e. the overall architecture on an abstract level.

- OpenVibe
- BCILAB
- ...
- my Design

Having explained the problem, and what others have done in similar situations, now explain your approach. Again, give a general overview of your design first, and then go into detail. The important part here is the concept of your work, not the actual implementation! Make sure that the document (particularly a thesis) is self-contained: It should be possible for a reader familiar with the general area to understand your design. Again, be forthright about the limitations of your design. Also, make sure you justify any shortcuts/limitations convincingly.

2.2 Implementation

In this section, the implementation will be explained in greater detail.

- Chain of information processing
- Implementation in Matlab
- e

In many (not all cases) there is a clear difference between the general approach (design) and its implementation in your particular circumstances. The design may be more general than what you can do given time and resources. Or you have developed a general design, and are now implementing a prototype on particular hardware. Give all required details. It should be possible to understand all this without referring to the source code.
This will, in general, include extracts of actual algorithms and hardware components used. Don't list pages of C code, an electronic copy of the source will accompany the submission and should be available to the marker, so there's no point in killing extra trees to put it into the report. Source code, if included at all, goes into the appendix and not the main document.
Make sure you describe your implementation in enough detail. Someone who has nothing else but your thesis report to go by should be able to repeat your work, and arrive at essentially the same implementation. Reproducibility is an important component of scientific work. Also, clearly state the limitations of your implementation, and justify them.

2.3 Experimental Results

A thesis almost always has an experimental part, typically some comparison to other approaches. Benchmarking takes time, for running the experiments, but also for thinking them up in the first place, and for analysing the results. Plan accordingly to spend enough time here!
Think about what makes sense to measure, what you want to learn from your measurements. Think about what is really the relevant contribution of your thesis, and how you can prove that you have achieved your goals. Think about what you can measure in order to get a good insight into the performance of various aspects of your design, how you can distinguish between systematic and accidental effects, how you can convince yourself that your results are right. If you get surprising results, don't just say "surprise, surprise, performance isn't as good as hoped". Find out why. Surprises without explanation indicate either that you are clueless about what's going on, or that you have made a mistake. Unconvincing results, therefore, tend to imply unconvincing marks.

Statistics: Measurements always have statistical (sampling) errors. Owing to the deterministic nature of simulations these are sometimes very small, as disturbing factors can be designed. However, the reader should be given an indication of how statistically significant the results are. This is done by providing at least a standard deviation in addition to averages. Whenever the results of several runs are averaged, a standard deviation can (and must) be supplied. After all, you average to reduce statistical errors.
The reproducibility argument applies here just as much as for the implementation.

Give enough detail on what you measure, and how you measure it, so that someone who has your implementation (but not your test code) or has re-done your implementation independently, should be able to repeat your measurements and arrive at essentially the same results. In some cases, results seem outright wrong in a thesis. In those cases, not enough detail is provided to allow the supervisor/reader to pinpoint the likely source of the error. Often the cause is systematic errors resulting from an incorrect measurement technique. If it seems wrong, and the text doesn't convince the reader that it is not wrong, the reader will assume that it is wrong.

2.4 Discussion

Discuss and explain your results. Show how they support your thesis (or, if they don't, give a convincing explanation). It is important to separate objective facts clearly from their discussion (which is bound to contain subjective opinion). If the reader doesn't understand your results, reconsider if you have managed to extract the core information and explain it in a straightforward way.

Chapter 3

Conclusion

Don't leave it at the discussion: discuss what you/the reader can learn from the results. Draw some real conclusions. Separate discussion/interpretation of the results clearly from the conclusions you draw from them. (So-called "conclusion creep" tends to upset reviewers. It means surrendering your scientific objectivity.) Identify all shortcomings/limitations of your work, and discuss how they could be fixed ("future work"). It is not a sign of weakness of your work, if you clearly analyse and state the limitations. Informed readers will notice them anyway and draw their own conclusions, if not addressed properly.

Recap: don't stick to this structure at all cost. Also, remember that the thesis must be:

- honest, stating clearly all limitations;
- self–contained, don't write just for the locals, don't assume that the reader has read the same literature as you, don't let the reader work out the details for themselves.

This chapter is followed by the list of figures and the bibliography. If you are using acronyms, listing them (with the expanded full name) before the bibliography is also a good idea. The acronyms package helps with consistency and an automatic listing.

List of Figures

Bibliography

[1] J. Meng, S. Zhang, A. Bekyo, J. Olsoe, B. Baxter, and B. He, "Noninvasive electroencephalogram based control of a robotic arm for reach and grasp tasks," *Scientific Reports*, vol. 6, 2016.

[2] X. Yong and C. Menon, "Eeg classification of different imaginary movements within the same limb," *PloS one*, vol. 10, no. 4, p. e0121896, 2015.

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