Course Project Guidelines for ELG5132 Smart Antennas

The project for this course includes a mini literature review about a specific problem selected by a student and approved by an instructor and a mini-research of this problem by a student. Topics should be relevant to the course content but otherwise arbitrary. Double submission of the same work (e.g. for thesis and as project for this course as well as two students submitting identical or nearly identical work) is not acceptable.

The project includes a brief presentation (about 5-10 min.) of the selected papers in **early November,** a final presentation (about 15-20 min.) of its activities by the end of the semester and a project report, by a student. Schedule and deadlines will be announced later on. In your brief presentation, you have to (i) introduce the topic you selected and explain why you believe this is good topic to study, and (ii) the papers you have selected and explain why you believe they are good papers. For your presentations, one slide approximately corresponds to 1 minute. Practice several times in advance to make sure your presentation is within the time limit and goes on smoothly. More guidelines are available on the course web page.

What to do:

1. Select a topic from the list below. You may suggest your own topic, but it needs an instructor's approval.
2. Find and read 3-5 major, i.e. full-length (>=5pages), journal papers, preferably – by different authors/groups, published in major (reputable) journals (e.g. IEEE Transactions etc.). Use IEEE Xplore. Papers should be recent (i.e. within 5 years). Older papers are acceptable if they are of major value. Try to identify major papers (i.e. most important). Avoid IEEE Communication Magazine (and similar) papers as they do not provide enough details to repeat the simulations and have very limited value. Be aware that many conference papers are of low value and hence should be avoided (unless you make sure that the selected papers are of significant value). Looking for citation numbers on Google Scholar can give some indication of value (however, keep in mind that recent papers need time to collect citations and some low-value "review" papers can have disproportionally large citations).
3. Clearly identify key ideas/results in each paper (usually, not more than 3 per paper). What is their strength? Weakness? Importance? Are they correct/wrong? Why?
4. Compare the results/ideas in the different papers you read. Give comparative analysis.
5. Select one most important paper and repeat the key simulations. Do you get the same results? Why?
6. Explain how the results can be extended/improved? Justify this and do simulations for an extended case. Compare with the original results and make conclusions.
7. Summarize what you have learned in this project. Suggest directions for future research. If you would do MS/PhD research in this area, what in particular would you do? Why?
8. For the presentation, prepare about 15-20 slides, which should fit into a 15-20 min. talk. See the course web page on how to prepare a good/bad presentation. It is essential that you

practice presentation several times before making it in the class (also to make sure that you fit into 15-20 min. time slot, which will be strictly enforced).

Parts 1, 2 and partially 3 have to be finished within 3 weeks of the posting of these Guidelines, approximately by middle of the semester; more details will be announced in the class. You will have to make a brief presentation (about 10 min.) at that time.

Based on your completed project work, you will give a presentation (about 20 min. long + question period) in the last few weeks of the semester.

Finally, you will summarize all your project work in a technical report as explained below. The due date for the report is the last class.

Things to remember when preparing your project report:

- The report must include the following parts: Title page, Table of contents, Summary (abstract), Introduction, Main part (review of the current literature, critical discussions and comparisons, your own contribution), conclusion, list of references, appendices. The papers you used must be attached as an appendix.
- Include explicit statement of the novelty at the beginning (after the abstract), explaining what is your own novel contribution to the field.
- All the ideas borrowed from other sources must include an explicit reference to those sources (otherwise it will be considered a plagiarism). If you use a word-by-word extract, you must use quotation marks rather than just a reference.
- When marking the report, I will be looking for your personal contribution to the field. Please keep this in mind when preparing the report.
- Please do not include just a re-phrased abstracts and conclusions of the papers you read. Include your own assessment of the results and techniques, emphasizing their advantages and drawbacks. Your report must indicate that you do understand those papers.
- Please remember what year is today. Hence, up-to-date references must be included (not just papers published 10 years ago). For the main papers, please include citation numbers (use Google Scholar to find it, scholar.google.com).
- There is a certain quality difference between journal and conference papers, the former being, as a rule, of much better quality. Keep this in mind when looking for the references.
- Do repeat some simulations reported in the references. This will insure that you understand the main techniques and will give you some ideas about the credibility of the results (in the papers as well as your own).
- Use 12 points font with 1 inch margins everywhere, single spacing and single column format. An approximate size of the report is about 20 pages without appendices. However, what matters is quality rather than just a page count.
- The report has to be bounded; the main 3-5 papers have to be attached as an appendix; all equations have to be numbered. Use standard book formatting as an example.
- Include the simulation code flaw chart in the main text (and explain it in details) and the source code in an appendix.
- Give clear and detailed enough explanations so that the report can be read without reading the references.

The points above are important as they are telling you what I am going to look for when marking the report.

Please keep in mind that copying (either from papers/books or from other students' reports) will be penalized and your mark will be significantly reduced. If you need to quote something, quotation marks and a reference to a source are mandatory.

Preparing good presentation:

- Prepare slides, expecting 1 slide/min. on average, e.g. 15 min presentation should be about 15 slides; bring a pdf file on a USB stick
- Include the key points, do not overcrowd the slides with details (equations, text etc.) – they will go to the report
- Take sufficient time for explanations, do not read from the slides, do not rush through
- Use bullet form presentation of the material, not the textbook style
- Remember common wisdom: "one picture worth 1000 words"
- Number all slides and equations
- Introduce yourself
- Be prepared to answer questions
- Your presentation should clearly show the amount of work done and what you have learned
- Practice the presentation several times before making it in the class
- Give a printout (2-4 slides per page) to the instructor
- See the course web page for more advice

Criteria for marking:

- Ability to clearly present the research topic, including concise literature review (in both the report and presentation)
- Ability to demonstrate good understanding of all key points
- Ability to critically analyze selected 3-5 papers (what is good, bad in each paper, which paper is the best, why so)
- Ability to support each conclusion/judgment by clear arguments
- Original contributions of the project
- Justified suggestions of how to improve the reported results and/or the problems found
- How efficient the report/presentation is in communicating the message to the audience
- How closely the guidelines above have been followed

Topics for mini-project: ELG5132 Smart Antennas

1. Propagation channel modeling for smart antennas and MIMO.
2. Smart antennas for wireless systems: major benefits (include system level analysis).
3. AOA estimation algorithms: recent developments. This may include MUSIC, ESPRIT, etc.
4. MMSE/Max. SNR beamforming: recent developments (e.g. channel uncertainty, various constraints, etc.).
5. Smart antenna prototyping and implementation issues.
6. Beamforming networks: design & implementation.
7. Digital beamforming implementation.
8. Robust adaptive beamforming (also known as beamforming with channel uncertainty or channel estimation errors). This may include beamforming based on worst-case performance optimization, robust minimum variance, MMSE or max. SNR beamforming.
9. Applications: adaptive beamforming for underwater acoustic systems.
10. Applications: adaptive beamforming for radar systems.
11. Applications: microphone array hearing aids (including interference and noise cancellation).
12. Smart antennas and software radio.
13. Smart antenna analysis and Schwarz inequality.
14. Iterative algorithms for smart antennas.
15. Co-channel interference reduction using smart antennas.
16. Capacity increase of cellular systems using smart antennas.
17. Diversity combining:.
18. Diversity combining: recent developments and performance analysis.
19. Impact of channel estimation error on combiner's performance.
20. Capacity studies of MIMO systems.
21. Rx processing for MIMO: D-BLAST, V-BLAST, ML-BLAST, other…
22. Tx precoding in MIMO systems.
23. Iterative algorithms for MIMO systems.
24. Adaptive MIMO systems.
25. Multiuser MIMO systems.
26. Relay MIMO channels.
27. Models of correlated MIMO channels (Kronecker model etc.).
28. BER analysis of MIMO. Performance bounds.
29. MIMO prototyping and implementation.
30. MIMO transmission over uncertain channels (channel estimation error).
31. Impact of channel state information (CSI) on MIMO systems (e.g. instantaneous, average etc.).
32. Smart antennas/MIMO systems in 4/5G wireless systems (UMTS, LTE, WiMAX, IEEE802.11/16, WiFi, etc.).

33. Smart antennas/MIMO systems in wireless networks or multi-user systems.
34. Smart antennas/MIMO systems in sensor networks.
35. Smart antennas/MIMO systems in cognitive radio networks.
36. Distributed/virtual antenna arrays/MIMO system.
37. Massive MIMO. 5G and 6G applications.
38. Cell-free MIMO.
39. Collaborative communications.
40. Physical layer security in wireless networks, including MIMO.
41. Optimal beamforming/MIMO via convex optimization or game theory.
42. Interference alignment in wireless systems/networks.
43. MIMO: wireless information and energy transfer.
44. Orbital angular momentum (OAM) MIMO systems.
45. MIMO systems/channel capacity under per-antenna and total (joint) power constraints.
46. MIMO systems/capacity under interference constraints.
47. Smart antennas for millimetre-wave (mmWave) systems.
48. New applications of MIMO.

List of Suggested Papers

Note: you have to add some papers that are not indicated here into your project. Please do include recent papers, not just those published 10-20 years ago.

Please also note that only selected areas are represented on this list. Feel free to make a choice of your own.

Basic MIMO Principles/Architectures

[1] I.E. Telatar, "Capacity of Multi-Antenna Gaussian Channels," *AT&T Bell Lab. Internal Tech. Memo.*, June 1995 (European Trans. Telecom., v.10, N.6, Dec.1999).

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[12] C. Rao, B. Hassibi, Analysis of multiple-antenna wireless links at low SNR, *IEEE Transactions on Information Theory*, v. 50, N.9, pp. 2123 – 2130, Sept. 2004

[13] D. Chizhik, Slowing the time-fluctuating MIMO channel by beam forming ; *IEEE Transactions on Wireless Communications*, v. 3, N.5, pp. 1554 – 1565, Sept. 2004.

BLAST

[14] G. D.Golden, G. J.Foschini, R. A.Valenzuela, and P. W.Wolniansky, "Detection algorithm and initial laboratory results using the V-BLAST space–time communication architecture," *Electron. Lett*., vol. 35, no. 1, pp. 14-15, 1999.

[15] G.J Foschini et al, Simplified Processing for High Spectral Efficiency Wireless Communication Employing Multi-Element Arrays, *IEEE Journal on Selected Areas in Communications*, v. 17, N. 11, pp. 1841-1852, Nov. 1999.

[16] G.J. Foschini et al, Analysis and Performance of Some Basic Space-Time Architectures, *IEEE Journal Selected Areas Comm*., v. 21, N. 3, pp. 281-320, Apr. 2003.

[17] E. Biglieri, G. Taricco, A. Tulino, Decoding space-time codes with BLAST architectures, *IEEE Trans. Signal Proc*., v.50, N.10, pp. 2547-2552, Oct. 2002

[18] M. Sellathurai, S. Haykin, TURBO-BLAST for wireless communications: theory and experiments, *IEEE Trans. Signal Proc*., v.50, N.10, pp. 2538-2546, Oct. 2002

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Space-Time Coding/Modulation

[30] V. Tarokh, N. Seshadri, A.R. Calderbank, Space-Time Codes for High Data Rate Wireless Communication: Performance Criterion and Code Construction, *IEEE Trans. Information Theory*, v. 44, N. 2, pp. 744-765, Mar. 1998.

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MIMO Channels/Capacity

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Smart Antennas/Beamforming

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