ACS6124 Multisensor and Decision Systems
Part II: Decision Systems for Engineering Design

Assignment 2023/24

ACS6124 incorporates two assignments – one for each Part of the module. This document introduces the assignment for Part II, providing submission instructions, a detailed assignment briefing, and the marking criteria.

Assignment weighting:	50% of the module
Assignment released:	24 April 2024 (Wednesday, Week 9)
Assignment due:	12 noon, 20 May 2024 (Monday, Exam Week 1)
Format:	A report of 15 pages maximum (using a top and bottom margin of 1.5 inches, a left and right margin of 1 inch, text of size 12 point, with 1.5 line spacing). The report must be submitted electronically via BlackBoard.
Assignment code:	ACS6124-002

Penalties for late submission
Late submissions will incur the usual penalties of a 5% reduction in the mark for every working day (or part thereof) that the assignment is late and a mark of zero for submission more than 5 working days late. For more information, see:
https://www.sheffield.ac.uk/ssid/assessment/grades-results/submission-marking

Unfair means
This is an individual assignment. You should not discuss the assignment with other students or work together with other students in its completion. The assignment must be wholly your own work. References must be provided to any other work that is used as part of the assignment. Any suspicion of the use of unfair means will be investigated and may lead to penalties. For more information, see: https://www.sheffield.ac.uk/ssid/unfair-means

Extenuating circumstances
If you have any medical or special circumstances that you believe may affect your performance on the assignment then you should raise these with the Module Leader at the earliest opportunity. You will also need to submit an extenuating circumstances form. For more information, see:
https://www.sheffield.ac.uk/ssid/forms/circs

Help
If you have any questions on the assignment, please email me at: r.purshouse@sheffield.ac.uk

Feedback
Written feedback will be provided on Blackboard within 15 working days, in line with Department guidelines.

Assignment briefing

Imagine you are a recent graduate who has decided to build a start-up company working on decision systems for engineering design. Your first potential client is a company working on a new type of electric-powered vehicle. While their team is capable of designing the new powertrain, they have limited experience in designing the rest of the vehicle: for example they need to implement a suitable controller for their propulsion system and are not sure how it might affect the dynamic performance of the vehicle, including its energy efficiency.

Your task is to convince them that your start-up company is perfectly suited to help them in the decision making process. To do that, they have asked you to prepare a report to highlight the capabilities of the tools you are proposing to use. Because at this stage they are reluctant to share their Simulink models, your pilot study will focus on tuning the gains for a Proportional-Integral (PI) controller, such that a feedback control system satisfies a set of requirements.

The system to be controlled, and the performance criteria against which a set of controller gains are assessed, are described in the Laboratory A instructions. The goals for the performance criteria are given in the instructions for Laboratory B.

During Laboratory A, you will learn about the relationships between the design variables and the performance criteria for the given system. In Laboratory B, you will attempt to optimize the gains to meet the goals for the performance criteria.

Following these laboratories, you need to write a report that would appeal to both the CEO of your potential client and their Chief Engineer. As you write, you will have further time to explore the system and perfect your analysis in the open Laboratory C. You need to convince the CEO that multi-objective optimization is the best way to approach the decision making. So far, her company have used opinions from experts and developed prototypes to validate their designs. In addition, you need to have a technical part in which you show their Chief Engineer what your pilot study has managed to achieve, explaining any challenges encountered in satisfying all the requirements, and making recommendations for tuning options.

Your report should be structured as follows:

> *Title page including Executive Summary* (**1 page**)
> Summarise the outcomes of the tuning process and recommendations for PI gain settings in **under 300 words**. This section does not contribute to the page limit for the report.
>
> *Section 1: Multi-objective optimization for Engineering Design* (**2 pages**)
> Write a brief introduction to Decision Systems for Engineering Design. Explain how it compares with other approaches used in decision making and give five examples from the literature where it has been used for electric vehicle design. Draw a comparison between the main three approaches to solving multi-objective optimization problems; explain the main differences in their approach to find a candidate approximation set.
>
> *Section 2: Problem Formulation* (**1 page**)
> Express the problem in formal mathematical terms.
>
> *Section 3: Sampling Plan* (**2 pages**)
> Show at least three different sampling plans and analyse their space-filling performance. Identify a sampling plan to take forward.
>
> *Section 4: Knowledge Discovery* (**2 pages**)
> Use the evaluations from the chosen sampling plan to describe the relationships between the design variables and performance criteria.

Section 5: Optimization Process (**2 pages**)
Describe the optimization approach used and how goals were incorporated into the process.

Section 6: Optimization Results (**2 pages**)
Show the results of the optimization process, indicating whether or not the goals have been met, and the quantitative trade-offs inherent to the problem.

Section 7: Sustainability Analysis (**1 page**)
Highlight the trade-offs between minimising energy usage and meeting the other goals for transient performance. Assess the implications for transient performance if the control effort goal were to be tightened to **0.63 MJ**. Discuss potential changes to powertrain hardware or controller architecture that might help mitigate any performance issues.

Section 8: Recommendations (**1 page**)
Based on the knowledge discovery and optimization results, make recommendations for PI controller options for consideration by the Chief Engineer.

Section 9: Conclusions (**1 page**)
Link the results of your study with the vehicle propulsion problem your client is keen to solve. How would you apply the same methodology for their problem? Indicate at least two other decision systems tools that you propose to use to help them in their design problem.

References
Include complete citations for any works used in the report. This section does not contribute to the page limit for the report.

Appendix
Provide your Matlab code listings as an appendix to the report. The appendix does not count towards the page count for the report.

Marking criteria

The assignment will be marked out of 100. The marking criteria below provide guidance on the relationship between the quality of submission and the marks awarded. Note that the quality statements are *indicative* only – the actual mark awarded will be a holistic judgment of the *overall* quality of submitted work.

Mark awarded	**Expected attributes of the technical report**
70-100	• An executive summary that succinctly summarises the findings of the tuning process and recommendations for future action. • A coherent introduction to decision systems for engineering design, contrasting multi-objective optimization to other approaches to decision support. Accurate description and comparison of the three major classes of multi-objective optimizer. • A problem formulation that correctly interprets the problem features in the language of constrained multi-objective optimization, including identification of design variables, parameters, objectives and constraints. • A set of at least three sampling plans that have been correctly assessed in terms of their space-filling properties. • Appropriate and creative data mining and visualisation of the sampling plan evaluation, identifying key relationships between design variables and objectives (e.g. regions of stability, trade-offs between aspects of transient performance). • A clear description of the optimization approach used, including how Chief Engineer preferences were incorporated into the search process. • Appropriate and creative data mining and visualisation of the results of the optimization process, identifying the level of success achieved and areas of conflict. • Accurate and comprehensive analysis of the trade-offs between minimising control effort, meeting goals for control effort, and delivering against other transient performance criteria. Identification of at least one credible change to the system or controller architecture that could potentially address some of these trade-offs, with justification. • Accurate and comprehensive sustainability analysis of the trade-offs between minimising energy usage and delivering other performance criteria, highlighting a range of possible trades that would satisfy the more stringent sustainability goal. • A coherent and credible set of recommendations for the controller gain settings, reflecting the results of the knowledge discovery and optimization processes. • Compelling association of the study findings to the client's vehicle design problem, indicating how the same methods could be used to deliver benefits, and highlighting two other decision systems tools that would be used alongside these methods. • Well-presented report, with appropriate use of labelled figures and few spelling or grammatical errors.

Mark awarded	Expected attributes of the technical report
60-69	• An executive summary that succinctly summarises the findings of the tuning process and recommendations for future action. • An introduction to decision systems for engineering design, and accurate description of the three major classes of multi-objective optimizer. • A problem formulation that correctly interprets the problem features in the language of constrained multi-objective optimization, including identification of design variables, parameters, objectives and constraints. • A set of at least three sampling plans that have been correctly assessed in terms of their space-filling properties. • A creditable attempt to identify key relationships between design variables and objectives through visualisation of the sampling plan evaluation (e.g. regions of stability, trade-offs between aspects of transient performance). • A clear description of the optimization approach used. • A creditable attempt to analyse the results of the optimization process, identifying the level of success achieved. • A creditable analysis of the trade-offs between minimising control effort, meeting goals for control effort, and delivering against other transient performance criteria. Identification of at least one credible change to the system or controller architecture that could potentially address some of these trade-offs, but with limited justification. • A creditable sustainability analysis of the trade-offs between minimising energy usage and delivering other performance criteria, highlighting at least one trade-off option that would satisfy the more stringent sustainability goal. • Recommendations for the controller gain settings that are largely grounded in the results of the knowledge discovery and optimization processes. • Linkage of the study findings to the client's vehicle design problem, highlighting at least one other decision system tool that would be used alongside these methods. • Generally well-presented report, with appropriate use of labelled figures and few spelling or grammatical errors.
50-59	• An executive summary that includes an attempt to summarise the findings of the tuning process and makes recommendations for future action. • An introduction to decision systems for engineering design, with an accurate description of at least one of the classes of multi-objective optimizer. • A problem formulation that interprets the problem features in the language of constrained multi-objective optimization, but where the formulation may contain some missing or unclear elements. • An appropriately visualised sampling plan. • Some attempt to identify key relationships between design variables and objectives through visualisation of the sampling plan evaluation (e.g. regions of stability, trade-offs between aspects of transient performance). • A description of the optimization approach used, although some aspects may not be clearly described. • A creditable attempt to analyse the results of the optimization process, identifying the level of success achieved. • A creditable analysis of the trade-offs between minimising control effort, meeting goals for control effort, and delivering against other transient performance criteria. • A creditable sustainability analysis of the trade-offs between minimising energy usage and delivering other performance criteria. • Recommendations for the controller gain settings that are largely grounded in the results of the knowledge discovery and optimization processes. • Some indication of how the study findings link to the client's vehicle design problem, indicating how the same methods could be used to deliver benefits, highlighting at least one other decision system tool that would be used alongside these methods. • Generally well-presented report, with appropriate use of labelled figures and few spelling or grammatical errors.

Mark awarded	Expected attributes of the technical report
40-49	• An executive summary that provides a readable summary of the report, but is lacking focus on findings and recommendations. • An introduction to decision systems for engineering design, with a description of at least one of the classes of multi-objective optimizer. • A problem formulation that interprets the problem features in the language of constrained multi-objective optimization, but where the formulation may contain some missing, unclear elements, or incorrect elements. • An appropriately visualised sampling plan. • Lacking a convincing analysis of the key relationships between design variables and objectives through visualisation of the sampling plan evaluation (e.g. regions of stability, trade-offs between aspects of transient performance). • A description of the optimization approach used, although some aspects may not be clearly described. • Results of the optimization process are presented, but these are not analysed. • Limited analysis of the trade-offs between minimising control effort, meeting goals for control effort, and delivering against other transient performance criteria. • Limited sustainability analysis of the trade-offs between minimising energy usage and delivering other performance criteria. • Lacking recommendations for the controller gain settings, or recommendations that do not relate to the results of the knowledge discovery and optimization processes. • Lacking indication of how the study findings link to the client's vehicle design problem, although highlighting at least one other decision system tool that would be used alongside the methods employed. • Issues with the presentation of the report, with numerous grammatical errors and figures that are missing labels.
0-39	• Missing or incoherent executive summary. • Lacking an introduction to decision systems for engineering design and/or substantial inaccuracies in the description of multi-objective optimizers. • Missing or incoherent problem formulation. • Some evidence of a sampling plan, but unclear what this looks like. • Lacking a convincing analysis of the key relationships between design variables and objectives through visualisation of the sampling plan evaluation (e.g. regions of stability, trade-offs between aspects of transient performance). • Missing or incoherent description of the optimization approach used. • Missing the results of the optimization process. • Lacking analysis of the trade-offs between minimising control effort, meeting goals for control effort, and delivering against other transient performance criteria. • Lacking sustainability analysis of the trade-offs between minimising energy usage and delivering other performance criteria. • Lacking recommendations for the controller gain settings, or recommendations that do not relate to the results of the knowledge discovery and optimization processes. • Lacking indication of how the study findings link to the client's vehicle design problem and absence of consideration of other decision system tools that could be used alongside the methods employed. • Major issues with the presentation of the report, with numerous grammatical errors and figures that are missing labels, such that the meaning in the report is hard to discern.