KTH Royal Institute of Technology

Machine Department

Project Plan of IDIOM Group

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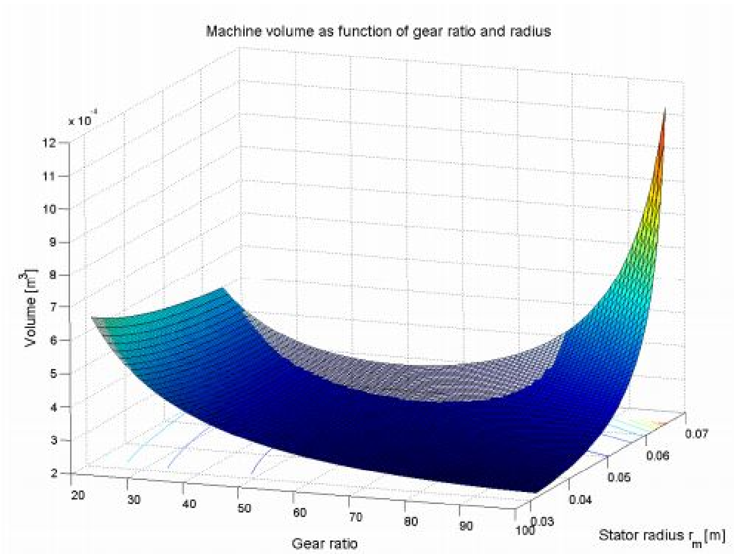

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1 Preliminary Title

The preliminary title at this stage is *Convex Optimization for Holistic Mechatronic System Design*. The title should indicate both the research context and the mathematical tool used. Therefore *mechatronic system* and *convex optimization* should be included in the title. Since the research is mainly focused on the modification of optimization algorithms, *methodology* has not been included in the title. The design methodology used emphasizes on a holistic approach, which is why *holistic* shall be included.

2 Background and Problem Description

This section presents the background and purpose to the research. The research question and the scope are formulated in the end of this section.

2.1 Backgroud

The target of the research is to explore the possibility of increasing the efficiency of one specific mechatronic design method by introducing new algorithm into the IDIOM software. The background is divided into two sections, one focusing on the design method of mechatornic systems and one focusing on genetic as well as convex algorithms.

2.1.1 Integrated Design and Optimization of Mechatronic Products

The development process of mechatronic products is challenging because it involves multiple engineering domains. In order to deal with them in an integrated manner as early as possible, several generic methodologies have been created, such as *V-model* and *Ulrich and Eppinger's model*. V-model, presented in [1], features frequent verification and validation against the requirements during the integration phases. Ulrich and Eppinger's model can be adopted in accordance with an unique context [2].

Although these methods have different formats, they do share something in common. According to [1] and [2], the detailed design is carried out based on rather abstract design in early phase, which means if some problems occur, chances are that the design in early stages needs to be modified as well. Moreover the lack of knowledge in early phase makes this kind of trace back inevitable [3]. To aid this issue, the *Integrated Design and Optimization of Mechatronic Products* (*IDIOM*) method has been created to explore the potential of concept design with limited information.

The IDIOM method treats the mechatronic system in a holistic pattern, integrating different domains in early design phase and optimizing parameters of designed structure with respect to one or multiple targets. Fredrik Roos contributed to the models of the method [4] and Malmquist et al. extended the capability of the method to attack several optimal objects at the same time. At this stage, controller has been included in the process to achieve true synergistic integration.

There has been a model library set up inside the IDIOM system with respect to both static and dynamic characteristics of those components. The approaches in different domains have been picked carefully to make the problem easy to solve under different configurations without too much lost detail. Therefore designers only need to pick and configure models from the model library and specify the design goal(s), the optimal solution of this specific design concept would be provided by the system [3].

2.1.2 Genetic Algorithm and Convex Optimization

The optimization algorithm used in IDIOM is *genetic algorithm* (*GA*). A GA is one of the most common non-gradient methods. It mimics the process of natural selection by treating each solution as an individual. The solution set after each iteration is called a generations. The individuals with higher objective function values have higher chance to produce their offspring by crossover. Meanwhile mutation is used to keep the diversity of solutions. After the evaluation of several generations, the algorithm may find optimal or sub-optimal solution [5].

Although a GA is probably most commonly used evolutionary method, it cannot guarantee a true optimum. Besides it is computational intensive [4]. Therefore Convex Optimization method is introduced.

Convex Optimization refers to the technology used to solve convex optimization problems, in which the objective function and constraint functions are convex. The advantages of formulating an optimization problem as convex are significant [6].

With the help of reliable tools, such as *CVX* toolbox [7] for matlab, the problems can be solved efficiently. Non-convex as the objective functions in IDIOM system might be, it is expected those problems could be modified or simplified as convex since many objective functions can be treat as composition of convex functions.

2.2 Research Question

The proposed research question is as follows.

How can convex optimization perform, in terms of computational speed, memory usage and precision, compared to genetic algorithms when optimizing a mechatronic servo system design.

2.3 Scope

The research will be delimited by the following constraints.

- The systems to be analyzed are mechatronic servo systems consisting of basic components such as motors, gearboxes and loads.
- Only components included in the IDIOM software will be used.

3 Method

The method used in this project is based on inductive reasoning. Case studies are to be performed on basic as well as advanced systems to determine if convex optimization performs better, in terms of e.g. computation speed and memory usage, than genetic algorithms when applied to mechatronic system design. Empiric data collected are used in the inductive reasoning process to arrive at a conclusion.

4 Timeplan

The time-plan related to the project is included in appendix A. It specifies milestones as well as tasks that are to be completed during the project. The initial four weeks include activities regarding individual literature studies and the writing of a common project plan. These weeks are followed up by two weeks of learning the basics of CVX toolbox found in MATLAB, and the IDIOM software. This knowledge will then be used in the next phase where three weeks are devoted to implement convex optimization of a basic case/system with volume as the target value. If the modification/simplification of the problem is harder than solving the actual optimization, the following step will focus on modification/simplification of more complex models with the same objective function. If it is the other way around, then different objective targets will be optimized for the basic system. This phase is shown as two parallel tasks in the time plan. The final report will be written concurrently during the project.

5 Risk Analysis

In this section, risks of the project are obtained from brainstorming. They are analyzed from different angles and among which, critical risks will be assessed further.

5.1 Risk Analysis Methodology

The methodology adopted to conduct the risk analysis is described as following steps:

1. Identify potential risks;
2. Determine probability;
3. Determine Impact.

As long as all possible risks are identified after brainstorming, they will be assessed according to the probability and impact respectively. Each aspect has a scale of 1, 3, and 9. A bigger number implies that the risk is more likely to happen or has a more serious consequence. Those risks of interest will be analyzed further based on their risk rating, which is defined as the product of probability and impact [8]. The risk matrix is shown in 5.1.

A risk matrix is shown in Table 1. The risks that lies in the upper right in red exceeds the level of tolerance and needs to be made action plan for.

		Impact		
		Low(1)	Medium(3)	High(9)
Likelihood	High(9)	9	27	81
	Medium(3)	3	9	27
	Low(1)	1	3	9

5.2 Risk Log

After the possible risks are identified, they are kept in table 2 following the priority of risk rating. The possible risks with high risk rating are marked in red and will be provided with an action plan below.

Table 1: Risk Log

No.	**Priority Hazard**	**Prob. (1-9)**	**Imp. (1-9)**	**Risk Rating (Prob.$\times$ Imp.)**
1	Estimates are inaccurate	9	9	81
2	Code error	3	9	27
3	Failure to follow the methodology	3	9	27
4	Preparation is inadequate	3	3	9
5	Knowledge integration	3	3	9
6	Info loss during communication	3	3	9
7	Ambiguous goal	1	9	9
8	Disagreement with the coa	1	9	9
9	Low morale (interests lost)	1	9	9
10	Tool selection problem	1	3	3
11	Software collapse	1	3	3
12	Misunderstand the requirement	1	3	3

5.3 Action Plan

An action plan is made for those risks with the highest likelihood and/or consequence. So the risks with risk rating above 9 are provided with the corresponding action plans. The following tables 2, 3 and 4 provide the action plans of items with high risk ratings.

Table 2: Action Plan for Item 1

Risk	Estimates are inaccurate
Location/Function	N/A
Summary (RECOMMENDED RESPONSE AND IMPACT)	
Inaccurate estimation is a common project risk and especially happens frequently for rookies. This risk will cause a series of project failure and the results of the project almost cannot be achieved. Gaining more experience can be a solution to this problem. It is recommended to consult the coach and learning from previous cases when making then estimation.	
1)Proposed Actions	Make considerate estimates patiently Check the progress regularly Consult with the coach
2)Resource Requirements	Time of the coach Previous similar project case Planned schedule
3)Responsibilities	The coach to be consulted about estimation rationality
4)Timing	Present the estimation at the nearest meeting after it is made. Check the progress once a week
5)Reporting/Monitoring	Each member has a milestone or individual sched--ule to achieve within given time

Table 3: Action Plan for Item 2

Risk	Code errors
Location/Function	Solver
Summary (RECOMMENDED RESPONSE AND IMPACT)	
Handling the code errorscan be time-consuming. To ensure that the programmer familiar with the expected results and reflect the idea to the code accurately.	
1)Proposed Actions	Test the code by comparing the results with the expected ones Read through the code logically
2)Resource Requirements	Time of the programmer Computer with installed related software Data from the previous work
3)Responsibilities	Programmer within the group
4)Timing	Check the code segments while coding Test the code after finishing coding
5)Reporting/Monitoring	Data documentation of previous work The report of new data to be finished

Table 4: Action Plan for Item 3

Risk	Failure to follow the methodology
Location/Function	Methodology
Summary (RECOMMENDED RESPONSE AND IMPACT)	
To ensure that each member get the individual work done within the deadline To ensure that the work is formulated based on the methodology.	
1)Proposed Actions	Set reasonable milestones and regular deadlines Check the achievement according to the schedule Formulate the work by methodology
2)Resource Requirements	Methodology to be adopted
3)Responsibilities	Everyone
4)Timing	Get the work done before the deadline Set milestones after work formulation
5)Reporting/Monitoring	Schedule or milestone plan report

References

[1] V. 2206, *Design methodology for mechatronic systems.* Dusseldorf: VDI-Verlag, 2004.

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[3] D. Malmquist, D. Frede, and J. Wikander, "Holistic design methodology for mechatronic systems," *Journal of Systems and Control Engineering*, vol. 228, 2014.

[4] F. Roos, *Integrated Design of Mechatronic Servo Systems.* PhD thesis, KTH Royal Institute of Technology, 2007.

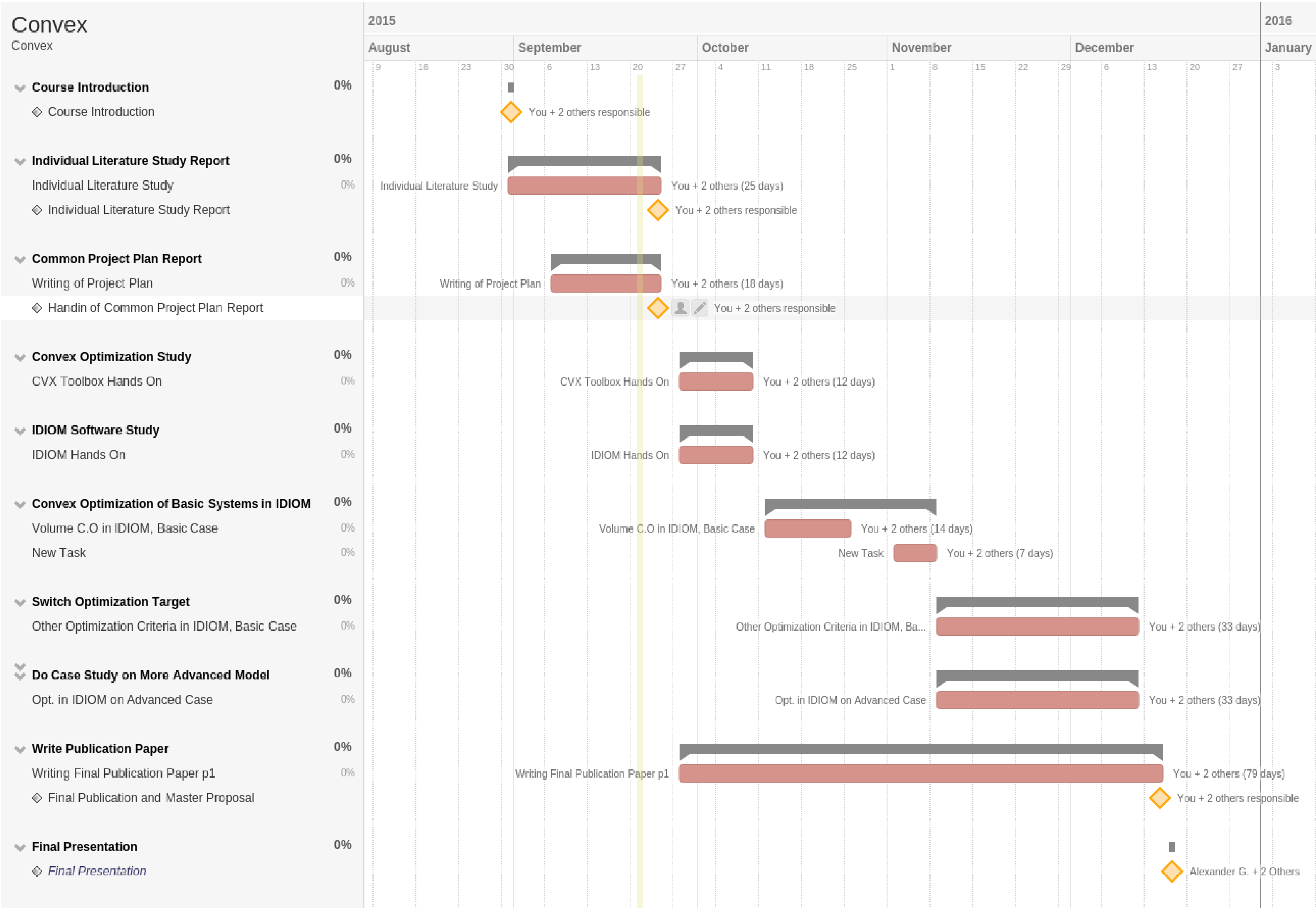
[5] W. Hare, J. Nutini, and S. Tesfamariam, "A survey of non-gradient optimization methods in structural engineering," *Advances in Engineering Software*, vol. 59, 2013.

[6] S. Boyd and L. Vandenberghe, *Convex Optimization.* New York: Cambridge University Press, 1st ed., 2004.

[7] M. C. Grant and S. Boyd, *The CVX Users' Guide.* CVX Research, Inc., 2.1 ed., 2015.

[8] E. Bonnie, "Project risk assessment." `https://www.wrike.com/blog/ultimate-guide-to-project-risk-part-1-risk-assessment/`. Accessed Sep. 15, 2015.

Appendix A


Convex
Convex
2015
2016
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27
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Course Introduction 0%
Course Introduction
You + 2 others responsible
Individual Literature Study Report 0%
Individual Literature Study 0%
Individual Literature Study Report
Individual Literature Study
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You + 2 others responsible
Common Project Plan Report 0%
Writing of Project Plan 0%
Handin of Common Project Plan Report
Writing of Project Plan
You + 2 others (18 days)
You + 2 others responsible
Convex Optimization Study 0%
CVX Toolbox Hands On 0%
CVX Toolbox Hands On
You + 2 others (12 days)
IDIOM Software Study 0%
IDIOM Hands On 0%
IDIOM Hands On
You + 2 others (12 days)
Convex Optimization of Basic Systems in IDIOM 0%
Volume C.O in IDIOM, Basic Case 0%
New Task 0%
Volume C.O in IDIOM, Basic Case
You + 2 others (14 days)
New Task
You + 2 others (7 days)
Switch Optimization Target 0%
Other Optimization Criteria in IDIOM, Basic Case 0%
Other Optimization Criteria in IDIOM, Ba...
You + 2 others (33 days)
Do Case Study on More Advanced Model 0%
Opt. in IDIOM on Advanced Case 0%
Opt. in IDIOM on Advanced Case
You + 2 others (33 days)
Write Publication Paper 0%
Writing Final Publication Paper p1 0%
Final Publication and Master Proposal
Writing Final Publication Paper p1
You + 2 others (79 days)
You + 2 others responsible
Final Presentation 0%
Final Presentation
Alexander G. + 2 Others