KTH Royal Institute of Technology

Machine Department

Project Plan of IDIOM Group

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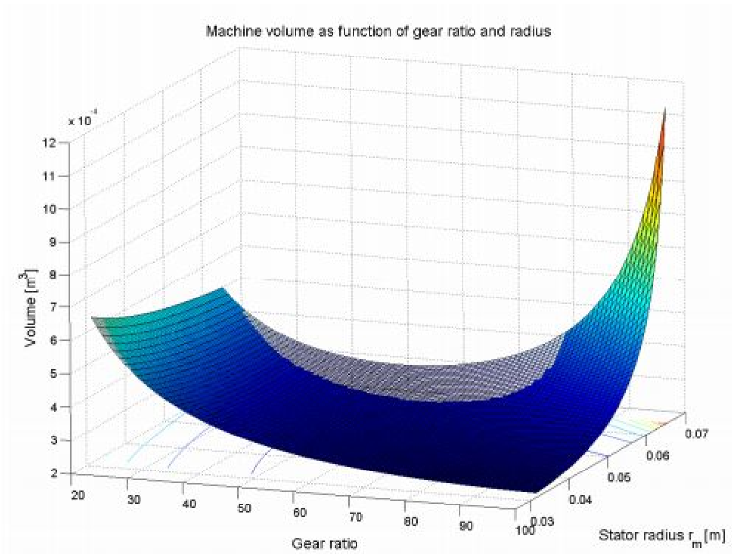

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1 Preliminary Title

This section presents the key words of the research and preliminary title.

1.1 Key Words

There has been an agreement reached within the group that the title should indicate both the research context and mathematical tool. Therefore *mechatronic system* and *convex optimization* should be included in the title. Since the purpose of research is mainly focus on the modification of optimization algorithms, *methodology* has not been included in the title.

1.2 Title

The preliminary title at this stage is *Convex Optimization for Mechatronic System Design*.

2 Background and Problem Description

This section presents the background and purpose to the research. The research question is formulated in the end.

2.1 Backgroud

The background is stated in two perspectives. Since the target of this research is to explore the possibility of increasing the efficiency of one specific mechatronic design method by introducing new algorithm to the solver, those two aspects are concerning the design method and algorithm respectively.

2.1.1 Integrated Design and Optimization of Mechatronic Products

The development process of mechatronic products is challenging because it involves multiple engineering domains at the same time. 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 traceback inevitable [3]. Therefore the *Integrated Design and Optimization of Mechatronic Products* (*IDIOM*) is 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 one creature. The solution set after each iteration is called one 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.

3 Risk Analysis

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3.1 Risk Analysis Methodology

The methodology adopted to conduct the risk analysis is described as following steps:
Step 1: Identify potential risks
Step 2: Determine probability
Step 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.

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

Figure 1: Risk Matrix

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.

3.2 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.

3.3 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 plan.

References

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

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

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[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.

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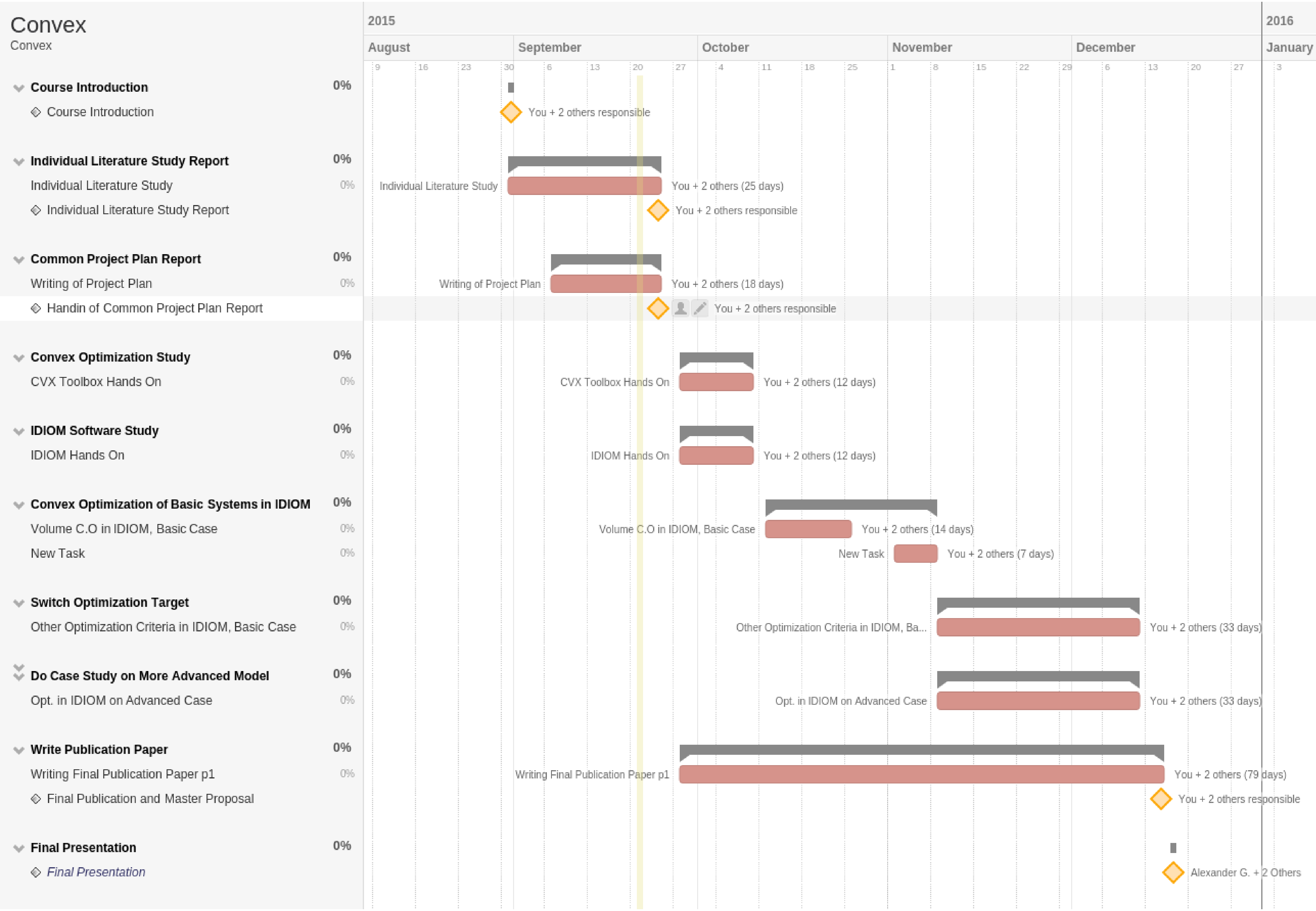
Appendices



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Course Introduction 0%
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Common Project Plan Report 0%
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IDIOM Software Study 0%
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Opt. in IDIOM on Advanced Case 0%
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Final Publication and Master Proposal
You + 2 others responsible
Final Presentation 0%
Final Presentation
Alexander G. + 2 Others