

Chapter 15

Optimization and Control for Systems in the Big Data Era: Concluding Remarks

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Abstract In the big data era, new research opportunities and challenges exist for systems optimization and control problems. In this concluding chapter, we share several probable related areas which may lead to fruitful research in the future. We also summarize the future research directions proposed by papers featured in this book.

Keywords Concluding remarks • Big data • Optimization • Control • Future research • Opportunities • Challenges

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271

15.1 Optimization and Control: Challenges and Opportunities in the Big Data Era

Big data optimization and control is an important topic. It is influential to not only business operations but also the society and science (Stefanowski and Japowicz 2016). One underlying principle of big data analysis is that: Having the big data, more useful information can be found than when we separate the big data into smaller datasets. This means we simply cannot separate the datasets and solve the big data problems properly in many cases (Sparks et al. 2016). In addition, in the presence of big data, we can explore more complex systems with a goal of improving their performance or even achieving optimization (Chan et al. 2016; Choi et al. 2016a, b). However, this goal is easier said than done because it involves a lot of technical challenges. In light of the challenging issues around big data optimization and control problems, based on the various Vs associated with big data, we propose a few areas for future research as shown below.

Volume The most basic element of big data is the huge volume of data. This is also related to high dimensionality of the datasets. This means the traditional optimization and control methods which work well for small datasets may not function well anymore. To cope with this challenge, the first proposal is to see if the big data problem can be solved by decomposing it. Even though not all big data problems can be solved by decomposition, some problems probably can. This approach is usually called the divide-and-conquer (Wang and He 2016). Moreover, new methods based on the parallelization approach (Daneshmand et al. 2015; Facchinei and Scutari 2015) can also be developed so that the smaller sized problems from the big problem can be processed in parallel. These provide rich opportunities for future research.

Velocity In optimization and control problems associated with big data, the emergence of data is quick and we also need to solve the problem in a timely manner. This creates challenges such as how we can achieve real time (or almost real time) optimization. New research on novel heuristics is probably needed to address this issue.

Variety The data available can be complex and not all of them are given in numbers. For example, in studying financial markets (Yao and Li 2013), on one hand, we have data such as historical records of indices and stock prices (Gao and Li 2013; Shi et al. 2015). On the other hand, we also have some expert advice, news, reports which are not directly expressed in numbers. How to combine them to formulate the optimal portfolio is a challenge and deserves deeper future research.

Veracity The big dataset may include missing information which means the data quality is not good. This creates uncertainty in the dataset and makes the respective optimization and control problem incomplete. New techniques (including dual control (Li et al. 2002), evolutionary optimization (Bhattacharya et al. 2016)) and even research methodologies (e.g., the multi-methodological approach

(Choi et al. 2016b), new framework (Boone et al. 2016)) need to be developed so that the optimization and control method can learn from “uncertainty” in the big data. Wang and He (2016) provide a recent discussion on the related research opportunities.

Value Big data potentially can yield a high or low value to the decision makers. It is hence important to measure the performance by conducting a proper performance analysis. Li et al. (2016) provide a review on the topic with a discussion on various performance tools for big data analytics. New research can be conducted to examine the proper performance tools and to help quantify the value of big data and the corresponding optimization methods.

15.2 Summary of Future Research Directions Highlighted in this Book

From the papers featured in this paper, various future research directions have been proposed. We summarize them in Table 15.1.

15.3 Concluding Remarks

In this concluding chapter, we have first discussed various challenges and research opportunities on optimization and control for systems in the big data era. We have already reviewed and reported the research opportunities proposed by the technical papers of this book. We hope the discussions can spark and inspire new research in optimization and control in the presence of big data.

Last but not least, we dedicate this book to our mentor Professor Duan Li, a true and distinguished scholar, a kind gentleman, an excellent professor, and an outstanding teacher who has made huge contribution to the advance of optimization and control theories. His theoretical works are also very influential and have been widely applied in financial engineering, industrial engineering, systems engineering, as well as many operations research related areas such as biomedical studies, production scheduling, and supply chain management, to name a few. We are very proud of being his students.

Table 15.1 Future research opportunities proposed in this book

Chapter	Paper	Future research opportunities	The related “V’s”
2	Fu	Dual controls with probing features are helpful to regulate complex systems in the big data era and deserve further explorations	Volume
3	Shi and Cui	In the big data era, more and more data-driven dynamic optimization problems are present, and many of them are time inconsistent (Cui et al. 2012) which create great computation challenges. This creates new research opportunities	Variety, velocity, veracity
4	Wu and Jiang	The quadratic convex reformulation can be further generalized based on the objective functions, constraints. The quadratic convex reformulation in the big data era is even more important than before because finding the best reformulation in the quadratic convex reformulation approach reduces to a stochastic dynamic programming problem, which is convex	Volume, velocity
5	Pei and Zhu	In exploring financial contagion, the methodologies have to consider timely and frequent collection, updating and integration of information emerged in the market. Future related research should address the above problems and many existing big data optimization techniques may be applicable to improve and conquer these challenges	Volume, value
6	Chiu	Applying the proposed method in asset liability management in the presence of big data would be a challenging task for future research	Value
7	Lu	Future research can be conducted on the quantum cryptosystems. Equipped with the rapid development of quantum theory and quantum computer, new insights on how objects behave at the microscopic level, can be learned from the big data available	Velocity, variety
8	Li, Li, Zhao	1. The channel coordination contract design under supply uncertainty 2. The effect of supply uncertainty on firm profitability should be evaluated in the context of the horizontal market competition 3. Other promising features to be explored in future research with the consideration of big data include information asymmetry, behaviors of decision makers, channel power and cooperation, and supply risk assessment	Veracity, value
9	Li, Li, Wu, Yao	Future research can be conducted on using the parameterized method to solve the portfolio selection problem when the returns are correlated in every period. New factors such as the presence of probability constraints, uncertain exit time, and Markov jumps will also be considered	Volume, veracity

10	Gao and Wu	Studying the stability issue of the out-of-sample test for the multiperiod mean-CVaR portfolio optimization problem is an interesting and challenging topic for future research	Volume, velocity
11	Liang	Future research can be carried out on the model statements and analysis. In particular, in order to improve the accuracy of the proposed models, new estimation methods for a large amount of parameters can be applied in the big data era	Volume, velocity
12	Yi	As introducing uncertain exit time adds extra risk to the investment, new measures have to be derived to deal with this challenge. It is an important future research direction	Volume, value
13	Wang, Zhuang, and Wu	In the big data era, it is important to examine the performance of the exact methods, and new heuristics may need to be developed to address larger sized problems. The big data technology could also provide a possible way to deal with the estimation errors of parameter in the new model, which also calls for more in-depth explorations	Volume, veracity
14	Choi	1. Examine the case with multiple products and the corresponding coordination challenges 2. Consider how social media data can be incorporated into quick response supply chain management 3. Adopt a multi-methodological approach with real data analyses	Volume, value
15	Choi et al.	1. Parallel optimization 2. Real time optimization 3. New methods to combine structured and unstructured data for optimization and control 4. New optimization and control techniques and methodologies to deal with data quality problems 5. New performance tools to quantify the value of big data	Volume, velocity, variety, veracity, value

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