Research on the all-English Course Construction of Optimization Computation for Graduates —— An Empirical Investigation Based on the Courses of Ten Engineering Colleges in the United States

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Abstract. Taking ten famous universities in the United States as examples, this paper introduces the teaching content of optimization courses in Engineering Colleges of American universities, and probes into the enlightenment of the opening of courses in American universities for the teaching of all-English optimization of public courses for graduates in China. It is proposed that the content of the all-English course of graduate optimization computation should be in line with the international standard, the teaching method should be changed to the seminar teaching, the internationalization level of graduate teaching should be improved, the ability of foreign graduates should be accepted and trained, the internationalization process of graduate education in China should be promoted, and the students should be trained as high-quality compound talents with innovative ability and in line with the international standards.

Introduction

Since the reform and opening up, China's graduate education has expanded its international influence and enhanced its voice in the world through various forms of international exchanges and cooperation, such as "introducing in" and "going out" [1]. In order to accelerate the goal of building a strong country with talents, and promote the construction of "double-first-class", in 2019, the state-sponsored graduate project for building high-level universities plans to send 10,000 people abroad to study for doctoral degrees or to jointly cultivate doctoral degrees [2]. One of the ten strategic tasks of "China Education Modernization 2035" is to create a new pattern of education opening to the outside world. It is necessary to comprehensively upgrade the level of international exchanges and cooperation and promote mutual recognition of academic degrees, standards and experience between China and other countries.

With the implementation of the strategy of "introducing in" and "going out", the number of foreign students studying in China and native students studying in abroad has increased year by year, which has aroused scholars' attention to the research on the quality of international graduate education [3,4]. From the interviews and questionnaires of overseas students in China, it is found that students hope to have more reasonable curriculum content and more interaction with teachers. At the same time, with the acceleration of the global internationalization process, more and more Chinese graduate students go abroad to exchange or study for doctoral degree, which will inevitably face the knowledge convergence and curriculum recognition. Therefore, it is urgent to improve and strengthen the construction of graduate curriculum system in English teaching. Taking the public graduate course, optimization computation, as an example and drawing lessons from ten famous universities in the United States, this paper explores the internationalized teaching contents, teaching methods and assessment methods of the public course for graduates, aims to promote the construction of all-English courses for graduates, improve the quality of courses and trains, train highly qualified and multi-disciplinary talents in line with the standards, which will contribute to the construction of world-class universities.

At present, the public course, optimization computation, for graduate students in universities is mainly for students in computer, telecommunications, power, materials, business administration and other colleges. Through the search of network resources, it is found that few universities in China

offer this course in English. For this reason, we investigated the courses, related to optimization computation, offered by ten famous engineering colleges in the United States. In the United States, the courses are often compulsory for graduate students and senior undergraduates of engineering colleges. The excellent textbook editors of optimization are mostly faculties in the department of electronic engineering or computer science.

Current Situation in America

The professional catalogue issued by the United States Department of Education in 2010 defines electrical engineering as the design, development and operation evaluation of electronic and electrical systems and their components using mathematical and scientific principles, including the analysis of electronic power generation systems and superconductors, wave propagation, energy storage and retrieval, reception and expansion. The main research contents include: communication and network, signal processing, electronics and integrated circuits, computer science and engineering, system control, power, photonics and optics, electromagnetics, microstructures, materials and devices, bioengineering, etc. Therefore, the computer science and the electronic engineering are mostly affiliated to engineering school in the United States.

Table 1. List of optimization courses offered by ten universities

University	School	Course
Stanford University	Engineering	Convex Optimization I
		Convex Optimization II
Massachusetts Institute of Technology	Engineering	Nonlinear Programming
University of Illinois	Engineering	Introduction to Optimization
Harvard University	Engineering and Applied Sciences	Introduction to Optimization: Models and Methods
Columbia University	Engineering	Convex Optimization
University of California, Berkeley	Engineering	Convex Optimization and Approximation
		Optimization Models in Engineering
University of Pennsylvania	Engineering and Applied Sciences	Introduction to Linear, Nonlinear and Integer Optimization
		Modern Convex Optimization
Yale University	Engineering and Applied Sciences	Optimization Techniques
Northwestern University	Engineering	Nonlinear Optimization
University of California San Diego	Engineering	Introduction to Linear and Nonlinear Optimization with Applications

Data Source: Official Website, September 2019

In order to ensure that the samples are representative and relevant data are easy to collect, we searched and collected the course information of ten famous engineering colleges in the United States through the official website of the university, as shown in Table 1.

In Stanford University, the optimization courses include convex optimization I and convex optimization II, which are arranged in winter and spring respectively. Convex optimization I focuses on the basic knowledge of convex analysis and convex programming theory, such as optimality conditions, duality theory, least square method, linear and quadratic programming, semi-definite programming, etc. The algorithms mainly introduce the numerical algorithms of smooth and equality constraints, the interior point methods of inequality constraints, and how to apply them to signal processing, communication, control, digital circuit design, computational geometry, statistics, machine learning and mechanical engineering. Convex optimization II focuses on non-smooth optimization algorithms. It mainly includes sub-gradient method, tangent plane method, monotone operator and adjacent method, alternating direction method of multiplier, and their applications in control, circuit design, signal processing and communication, and even global optimization and robust stochastic optimization.

In MIT, the course, nonlinear programming, provides a unified analytical and computational method for nonlinear optimization problems. Topics include unconstrained optimization, constrained optimization, convex analysis, Lagrange relaxation, non-differentiable optimization and its application in integer programming. Optimality conditions, Lagrange multiplier theory and duality theory are also discussed. Practical cases are extracted from control, communication, power system and resource allocation problems.

In University of Illinois, the introduction to optimization introduces basic theories and methods for solving optimization problems, unconstrained minimization, linear and non-linear programming, such as optimality conditions, quadratic programming, global analysis tools, convex analysis, dual theory and convex programming so on. Basic optimization algorithms include gradient descent method, gradient projection method, Newton method, conjugate gradient method, preconditioned conjugate gradient method, orthogonal polynomial, semi-infinite programming.

In Harvard University, the introduction to optimization focuses on models and methods by introducing basic mathematical ideas and computational methods for solving deterministic and stochastic optimization problems. Topics include linear programming, integer programming, branch and bound, branch and partition, Markov chain, Markov decision process. Emphasis is placed on modeling in business, society, engineering, sports and e-commerce.

In Columbia University, convex optimization includes basic convex optimization theory, commonly used numerical algorithms, and their applications in circuits, communications, control, signal processing and power systems.

In UCB, the course of convex optimization and approximation lay emphasis on optimization theory and method. The approximation of combinatorial optimization problem, stochastic programming problem, robust optimization problem and optimal control problem are studied, and their application in robust engineering design, statistics, control, finance, data mining and operational research are also discussed. The optimization model in engineering mainly introduces the common models in machine learning and statistics, decision-making and control, and focuses on the numerical methods of the model, such as constrained least squares optimization.

In the University of Pennsylvania, there are two courses about optimization. One provides a detailed introduction to linear and nonlinear optimization. The linear programming covers the Simplex method, sensitivity analysis, branch and bound, enumeration and cutting plane methods. The nonlinear programming includes steepest decent method, Lagrange multipliers, the KKT conditions and quadratic programming. In addition, many examples are selected from a broad range of engineering and business. The other course, modern convex optimization, concentrates on recognizing and solving convex optimization problems that arise in engineering. Topics include convex analysis, semidefinite programming, optimality conditions, duality theory, interior-point methods, barrier methods. And their applications to signal processing, control, digital and analog circuit design, computation geometry, statistics, and mechanical engineering.

In Yale University, optimization Techniques cover fundamental theory and algorithms of optimization, emphasizing convex optimization, such as convex sets, basic convex analysis, the principle of optimality, duality. Numerical algorithms focus on steepest descent, Newton's method, interior point methods, dynamic programming and applications in engineering.

In Northwestern University, nonlinear optimization introduces numerical solutions of unconstrained optimization problems, nonlinear least squares and nonlinear algebraic equations, large-scale nonlinear optimization, quadratic programming, constrained optimization, information domain method, line search, Newton method, constrained optimization theory and algorithms, sequential quadratic programming, multiplier method.

In UCSD, the course, introduction to linear and nonlinear optimizations, focuses on linear least squares problems, including constrained and unconstrained quadratic optimization and their relationship with linear transformation geometry, as well as how to apply them to signal processing, system identification, robotics and circuit design.

These optimization courses have two characteristics. First, they cover a wide range of optimization theory and algorithm and mostly concentrate in convex optimization, linear programming and

nonlinear programming, such as Simplex method, unconstrained optimization method, optimality conditions, dual theory, interior point method, multiplier method, even the proximal algorithm, alternating direction method of multiplier. Second, they emphasize how the optimization algorithm is used in different fields, and how to solve practical problems by solving mathematical models in the fields of circuit, communication, power, commerce, machine learning and so on.

Inspiration and Suggestion

Course teaching and scientific research are two closely related parts in the process of training graduates. The quality of curriculum plays an irreplaceable key role in the training of graduates, which is directly related to the construction of graduates' knowledge structure, the shaping of their innovative ability and the improvement of their comprehensive quality [5]. Optimization Computation is a compulsory course for graduates. The purpose of curriculum should highlight the professionalism and academics of master's training. The curriculum teaching should help graduates to get the theoretical basis of discipline and professional knowledge, cultivate academic interest and scientific research literacy, and at the same time improve their self-learning ability, critical thinking and innovative spirit, so as to enable students to compete with each other and carry out scientific research activities [6].

The construction goal of the all-English course of Optimization Computation is to integrate the teaching content with the international level, to build a problem-driven discussion-based teaching system that can reflect the frontier research results of the subject, to stimulate the enthusiasm of both "teaching" and "learning", to enable students to effectively understand the development trends of the course and to master the core of the optimization algorithm. The core idea and realization method can truly realize the knowledge reserve and scientific research preparation of master students, further improve the quality of graduate education, and contribute to the smooth implementation of the "double-first-class" construction. In the following, the teaching materials, methods, assignments will be discussed step by step.

Materials

In order to maintain the frontier and hierarchy of teaching content, we can draw lessons from foreign high-level textbooks to form our own characteristic lectures. In American the textbooks and contents of graduates have the characteristics of standardization and individuation [7]. Standardization refers to the requirement of "threshold" in the curriculum design and content selection of graduates. Professional courses need to be evaluated to confirm whether a course and its contents can be accepted as graduate courses. New courses need to be evaluated by academic committees after three consecutive years, and can be formally entered into the curriculum sequence only after they are qualified. Personalization means that the content of graduate courses emphasizes the frontier, which includes not only the hot and difficult points in the subject field, the controversial problems and new trends in research, but also the frontier contents of related subjects and interdisciplinary fields. For example, the content of the optimization course in Table 1 not only relates to the main neighborhood algorithms in compressed sensing and machine learning fields in recent ten years, but also emphasizes the specific application of optimization algorithms in engineering and business fields.

According to the textbook information published on the official website, the textbooks used by the universities in Table 1 include “Convex Optimization Algorithms” edited by Dimitri P. Bertsekas, “Convex Optimization” edited by Stephen Boyd and Lieven Vandenberhe, “Foundations of Optimization” edited by Osman Guler, and Yu. Nesterov. “Introductory Lectures on Convex Optimization” and so on. Dimitri P. These textbooks have different emphases. Based on these foreign textbooks, we have compiled seven lectures for discussion-based teaching of graduates, covering Lagrange duality, gradient-like methods, penalty function method, neighborhood algorithm, coordinate descent method, random gradient method and quadratic programming problem. It not only includes the introduction of optimization theory and methods, but also emphasizes the practical application of the algorithm. It fully considers the specific needs of enterprise scientific and technological research and development, and designs problem-solving exercises in interdisciplinary

fields. It is convenient to constantly update the content, enrich the knowledge structure of students and enhance the cross-disciplinary training.

Methods

Graduates take part in class teaching is essentially an academic participation that broadens academic horizons, cultivates academic interests, grasps frontier knowledge and research methods, and improves academic literacy and research ability [8]. Compared with undergraduates, graduates are relatively mature, independent, and have strong ability to accept new things and practical tools. They like seminar-based teaching and reject theoretical indoctrination-based teaching. In order to effectively mobilize students' learning enthusiasm, advanced teaching methods should be provided according to the teaching content, students' characteristics and the needs of English teaching.

According to the research of curriculum and textbooks in American universities, it is found that the course of Optimization Computation includes two parts: theoretical analysis and algorithm application. How to analyze the optimization theory in depth so that students can gradually understand and master the complex and abstract mathematical theories, such as optimality conditions and duality theorem, in discussion and thinking? The way of teaching is very important. Inspired by the teaching methods of MOOC teaching, discussion-based teaching and case-based teaching, and the fact that graduate students already have strong autonomous learning, it is necessary and effective to study the teaching mode of developed countries abroad, carry out problem-based lectures under the condition that students complete online learning of course in advance. It is necessary to supply open teaching mode, pay attention to the guiding role of teachers, mobilize the enthusiasm of graduate students to participate discussion, guide graduate students to ask questions and explore solutions in order to gradually cultivate graduate students' ability of scientific research.

Assignments

The ultimate goal of Optimization Computation for engineering students is to enable graduate students to use common optimization algorithms to solve practical problems by means of the study and implementation of algorithms. The understanding of algorithms must be combined with experiments. The exercises part of the course is mainly suitable for programming and implementation of experimental topics, requiring students to implement on the computer. Besides the correctness of experiments, teachers should give some questions according to experimental results, such as, the reason for the wrong results, the reason for the change of some parameters, the method to improve the accuracy and efficiency of calculation, and so on. This can promote the understand of the algorithms. In additions, homework should be based on practical problems in different fields. These optimization problems may be different but can be solved by the same optimization algorithm, and students can completely understand the essence of the optimization algorithm. Considering that the mother language of students is not English, the curriculum assessment is not only based on foreign experience, but mainly adopts three methods, namely, 40% homework, 35% traditional final exam and 25% seminar.

Summary

The course of Optimization Computation focuses on problem-driven and novel contents, closely following the current frontier achievements of optimization and hot issues in the application field. By means of the teaching contents and methods of famous American universities, graduates can understand and master the optimization algorithms by solving practical problems, so as to help students deepen their understanding of the professional fields. To a certain extent, the discussion-based teaching reduces students' communication barriers, helps students break through the understanding of difficult knowledge, quickly grasps the teaching content, promotes students' extracurricular reading, and breaks the existing teacher-centered teaching model. We hope to make full use of frontier and international professional knowledge and advanced teaching concepts, to promote students' professional learning, cultivate graduate students' academic literacy, broaden their international horizons, improve students' international competitiveness, and help them grow up to be

able to participate in international affairs and international competitiveness. In order to achieve the goal of building a research-oriented, comprehensive and open world-class university, a group of internationalized talents with broad international vision, innovative vitality and strong research ability should be trained.

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References

[1] Zhanjun Wang, Gang Qiao. Achievements and Prospects of China's Graduate Education in the Past 40 Years of Reform and Opening-up [J]. Degree and Graduate Education, 2018 (12): 7-13.

[2] https://www.csc.edu.cn/article/1410

[3] Weihua Cheng, Haibin Zhang, Weichun Dong. Research on the Quality of Graduate Education for Overseas Students in China under the Background of "Double-first-class" Construction: Based on Student Development Theory [J]. Degree and Graduate Education, 2019 (1): 64-71.

[4] Xin Jin, Linghui Tian, Binghua Liao, Shiting Cheng, Wenwu Liao. International Graduate Teaching and Learning Experience Survey: Based on a Case Study of a Research University [J]. Degree and Graduate Education, 2018 (3): 58-65.

[5] Xia Wang, Qing Bian and Junhua Sun. On the construction of academic degree graduate curriculum system [J]. Degree and graduate education, 2015 (10): 30-34.

[6] Shiting Cheng, Wenwu Liao. On the Construction of Academic Degree Graduate Course from the Perspective of Educational Ecology: Taking C9 University as an Example [J]. Graduate Education Research, 2017 (5): 49-54.

[7] Yi Sun, Luxi Chen, Chen Wang. International Experience and China Path in the Construction of Graduate Teaching Materials in Universities [J]. Degree and Graduate Education, 2018 (2): 72-77.

[8] Shan Wang. On the Essence of Graduate Students' Classroom Teaching Participation and Its Realization Ways. Graduate Education Research [J], 2017 (1): 43-46, 72.