

An Optimization Method for Cutting Stock Problem with Complex Application Requirements in Cloud Manufacturing

Dianjian Wu^a and Chunping Yan^b

The State Key Laboratory of Mechanical Transmission, Chongqing University,
Chongqing 400044, China

^acqu_wdj@163.com, ^byyp@cqu.edu.cn

Abstract. Aiming at that the existing optimization algorithms for cutting stock problem are unable to satisfy cutting stock problem with complex application requirements in continuous cutting stock process, an optimization method for cutting stock problem with complex application requirements is proposed from the perspective of cloud manufacturing. Meanwhile, a cloud service platform of cutting stock system is constructed to achieve this method in cloud manufacturing. Three key technologies for cutting stock cloud service, including classification management of cloud service, search matching of cloud service, dynamic scheduling of cloud service, are studied in this service platform. The feasibility of the proposed method for cutting stock problem with complex application requirements is verified by building the basic framework of the prototype system.

1. Introduction

The cutting stock problem (CSP) widely exists in many manufacturing industries, such as machinery, ship, iron and steel, furniture, paper making, glass, leather, etc [1]. Choosing suitable optimization algorithms for the specific CSP can reduce the material cost and enhance productivity, which is important to ensure the sustainable development of manufacturing industries.

In the practical production process, the CSP is not only a simple mathematical layout optimization problem, but also need to take into account other influential factors of cutting stock process, such as procurement plan for raw materials, constraint of cutting process, date due of product, etc. Therefore, it is necessary to fully consider complex application requirements (CARs) of cutting stock process during solving the encountered CSP.

Some scholars had proposed a large number of optimization algorithms for the CSP with different application requirements. Yan et al. [2] proposed a manufacturability-oriented one-dimensional CSP under complex constraints status, which was solved by a two-stage optimization method including non-fixed-length optimization method and fixed-length optimization method. Qin et al. [3] applied a group optimization method based on part shape similarity to deal with the CSP with large-scale parts. They tried to alleviate the contradiction between time efficiency and material utilization ratio when this type of CSP was solved. Cui et al. [4] established a mathematical model considering optimization objective of total cost for the one-dimensional CSP with setup cost, and used pattern-set generation algorithm to get a cutting plan with minimum total cost. Reinertsen and Vossen [5] introduced a mathematical model for one-dimensional CSP with date due, which was solved by combining a



column generation algorithm and a shortest date path algorithm. Those scholars all gave thier own optimization method for thier proposed CSP with one or several application requirement, but they can be unable to satisfy CSP with CARs because the real application requirement would be changed in continuous cutting stock process.

In recent years, Li et al. [6] have proposed a new network manufacturing mode - cloud manufacturing, which can organize online manufacturing resources and provide the corresponding manufacturing service according to users' needs through a cloud manufacturing service platform. As cloud manufacturing can provide a virtual sharing environment for mass manufacturing resources, it is convenient to solve the CSP with various application requirements. Therefore, this paper presents an optimization method for CSP with CARs from the perspective of cloud manufacturing.

The remaining paper is organized as follows. The optimization method for the CSP with CARs is introduced in section 2. The service platform for cutting stock system in cloud manufacturing is described in section 3. The prototype system of this service platform is reported in section 4, followed by conclusions in the final section.

2. Optimization Method for the CSP with CARs

2.1. CARs during Cutting Stock Process

Based on the analysis of cutting stock process, the CARs during cutting stock process are considered systematically. From the perspective of spatial dimension, the CARs can be divided into one-dimension, two-dimension, and three-dimension. The three-dimensional CSP is not considered because of its high complexity and uncommon application. Then from the perspective of time dimension, the CARs have six basic application requirements including stocks requirement, items requirement, leftovers requirement, date due requirement, cost requirement, and optimization performance requirement. The detailed structural classification of CARs during cutting stock process are shown in Fig. 1.

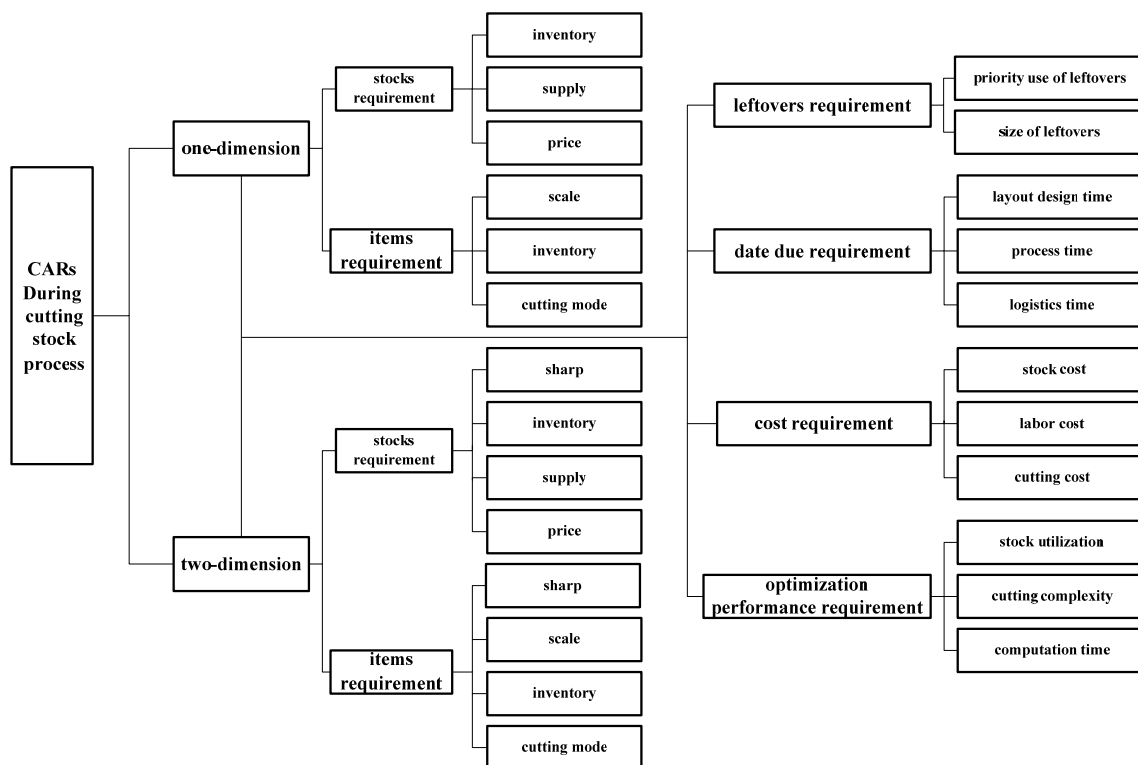


Fig. 1 Detailed structural classification of CARs during cutting stock process

(1) Stocks requirement: manufacturing industries have certain requirements of stock during cutting stock process. In order to reduce inventory pressure, they tend to use stock in their warehouse firstly. Meanwhile, Choosing which type of stock for current layout design may be decided by considering types, supply and price of stock in the market, synthetically.

(2) Items requirement: on the one hand, the size and demand of items for the CSP are formed according to the scale and existing inventory of items. On the other hand, it is necessary to consider the machining requirements of items and choose the suitable cutting mode.

(3) Leftovers requirement: leftovers often have higher priority than stock because it can save stock consumption. After cutting stock process is finished, the leftovers that meet the specified size can be stored to reuse in the future.

(4) Date due requirement: Date due of order task is important indicator. The layout time, process time, logistics cycle and other factors should be considered comprehensively when a cutting stock plan is established.

(5) Cost requirement: cost control is important indicator for a cutting stock plan. During designing layout for the CSP, the stock cost, labor cost and cutting cost are need to be taken into account to reduce the total production cost.

(6) Optimization performance requirement: the main optimization objective of the CSP is stock utilization. But the practical cutting stock plan often need to consider other auxiliary optimization objective, such as cutting complexity and computation time.

2.2. Method Design for the CSP with CARs

In the cloud manufacturing environment, each type of cutting stock resource can become an independent cutting stock cloud service (CSCS). A large number of those cloud services provide more possibilities for solving the CSP with CARs. For each CSP with specific application requirement, all CSCS that satisfying current application requirement are called to deal with the CSP, and get an optimal cutting stock plan for current CSP. This optimization method is realized with the help of cloud manufacturing technology and the existing research. The optimization design model of the method is displayed in Fig. 2.

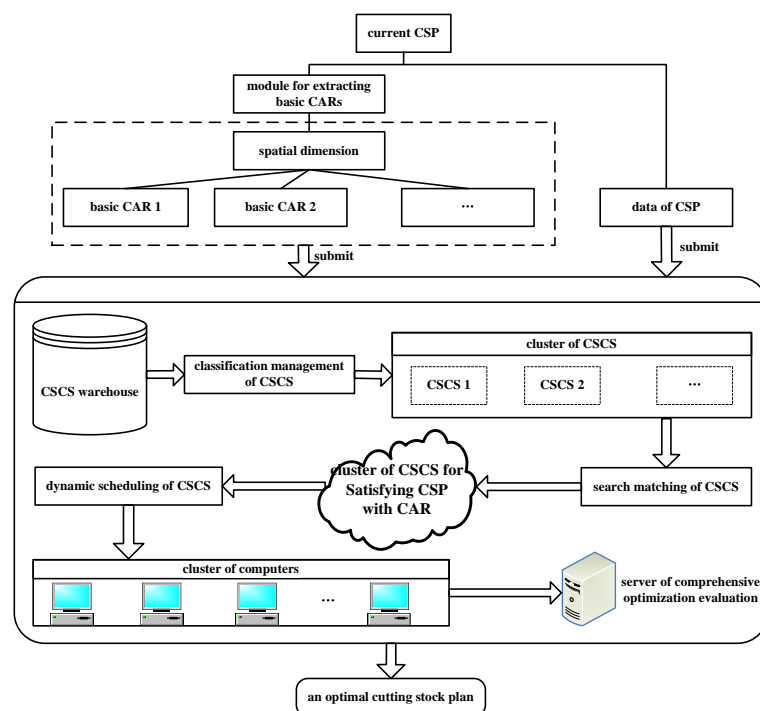


Fig. 2 Optimization design model of the method

In this optimization design model, the module for extracting basic CARs is used to get CAR of current CSP. Meanwhile, the data of this CSP is transferred into CSCS processing center and ready to be optimized. In the CSCS processing center, the classification management of CSCS is applied to form many clusters of CSCS from CSCS warehouse. The search matching of CSCS is used to select cluster of CSCS for satisfying current CSP, and the dynamic scheduling of CSCS is applied to distribute each CSCS to idle computer. By analyzed with a server of comprehensive optimization evaluation, an optimal cutting stock plan is achieved for current CSP.

3. Service Platform for Cutting Stock System in Cloud Manufacturing

3.1. Structure of Service Platform for Cutting Stock System

A cutting stock system service platform is proposed by combination of common cloud manufacturing system architecture [7] and traditional cutting stock system in this section. This service platform consists of seven layers: infrastructure layer, physical resource layer, virtual resource layer, core service layer, functional service layer, service interface layer and user access layer, shown in Fig. 3.

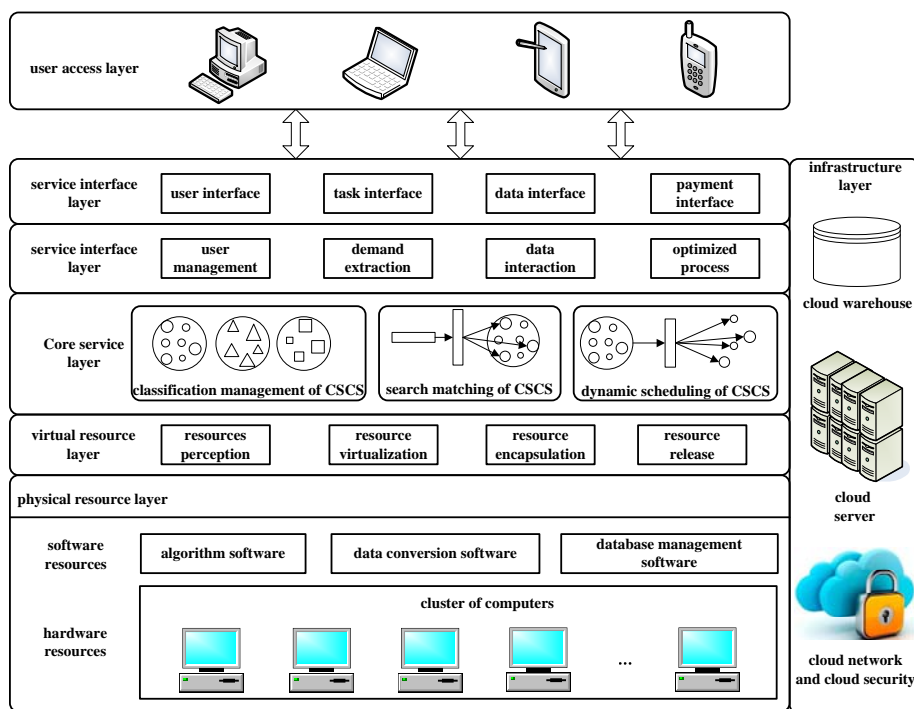


Fig. 3 A cutting stock system service platform for cutting stock system

(1) Infrastructure layer: this layer provides the most basic facility support for the entire system service platform, which mainly includes the cloud warehouse used to store a large number of layout data, the cloud server providing optimization of core services, and the cloud network and cloud security that ensures the normal and safe operation of the entire architecture.

(2) Physical resource layer: this layer consists of two parts: software resources and hardware resources. the software resources includes algorithm software, data processing software and database management software. The hardware resources are a series of computer used to complete the basic tasks, such as user basic information processing, user data processing, optimization algorithm layout processing, etc.

(3) Virtual resource layer: this layer is to transform the physical resource in the physical resource layer into manufacturing resource service cloud that can be identified and invoked. Physical resources

are transformed to manufacturing resource service cloud through a series of operations such as perception, virtualization, packaging and release.

(4) Core service layer: this layer provides intelligent management for manufacturing resource cloud service, including encoding rules for classification management of CSCS, the ontology semantic retrieval method for search matching of CSCS, service flow scheduling strategy for dynamic scheduling of CSCS, etc. These operation management ensures that the service platform can provide different CSCS with different application requirements for users.

(5) Functional service layer: this layer is mainly used to provide complete basic functions of users demand, including user management basic information, demand extraction, data interact, optimized process, and other functions.

(6) Service interface layer: this layer can be deemed to a connection channel between users and the service platform, and provide users with visual operation interface, which includes user interface, task interface, data interface, payment interface, and other interface.

(7) User access layer: this layer realizes the user's online access to CSCS. Access users only need to login this platform using a variety of terminal, such as PC terminal, mobile terminal, a dedicated terminal, etc. They can submit data of their solved CSP based on the specific data format, and obtain the corresponding CSCS.

3.2. Three Key Technologies for Cutting Stock Resource

(1) Classification management of CSCS

Core service layer is mainly scattered with numerous CSCS. In order to quick response of platform under the user's task request and improve efficiency of search matching and dynamic scheduling, the CSCS needs to be classified. The classification management of CSCS is based on structural classification of CARs during cutting stock process, and classified corresponding coding method of cloud service. The coding flow chart of CSCS is shown in Fig. 4.

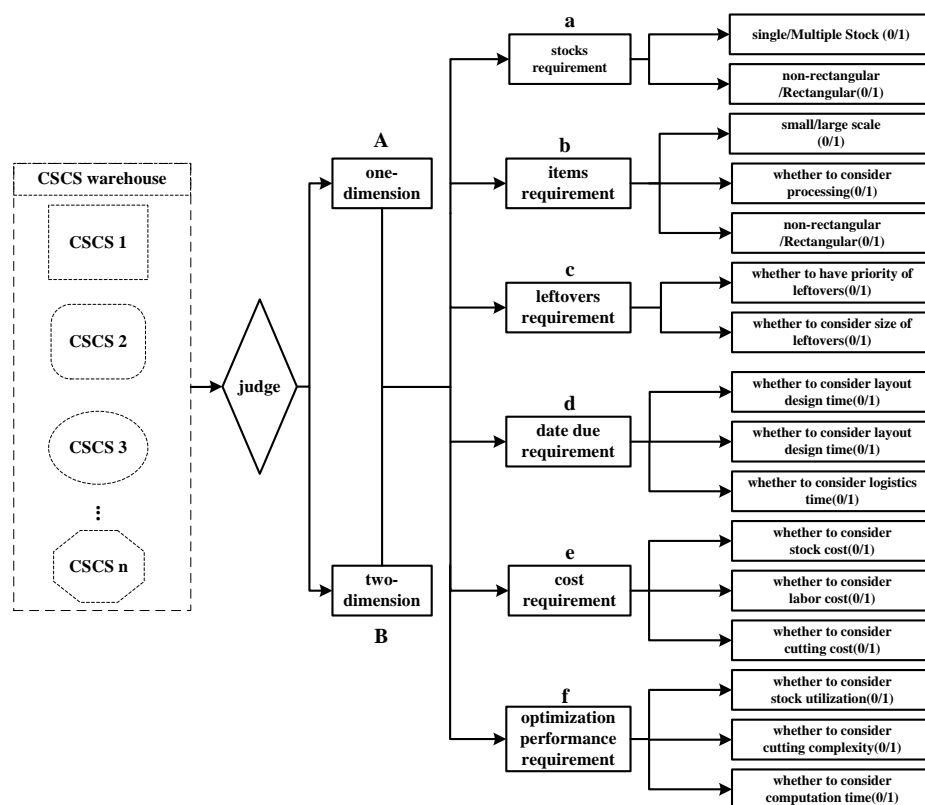


Fig. 4 The coding flow chart of CSCS

The specific implementation steps of the coding process are as follows: For each CSCS, firstly, to determine whether the dimension of this CSCS belonging to one-dimension or two-dimension, and use A or B to code it. Then to decide whether this CSCS including stocks requirement (coded by a), items requirement (coded by b), leftovers requirement (coded by c), date due requirement (coded by d), cost requirement (coded by e), optimization performance requirement (coded by f); and confirm the coded combination for it. Finally, to judge whether this CSCS considering the basic requirement, and apply 0/1 to denote inexistence or existence.

(2) Search matching of CSCS

The search matching of CSCS can realize that the suitable CSCS in the CSCS warehouse is searched and be matched for the specific basic application requirement of current CSP. This paper tried to combine classification management of CSCS and semantic retrieval technology based on ontology [8, 9] for accomplishing the search matching of CSCS. The flow chart figure of search matching of CSCS is displayed in Fig. 5.

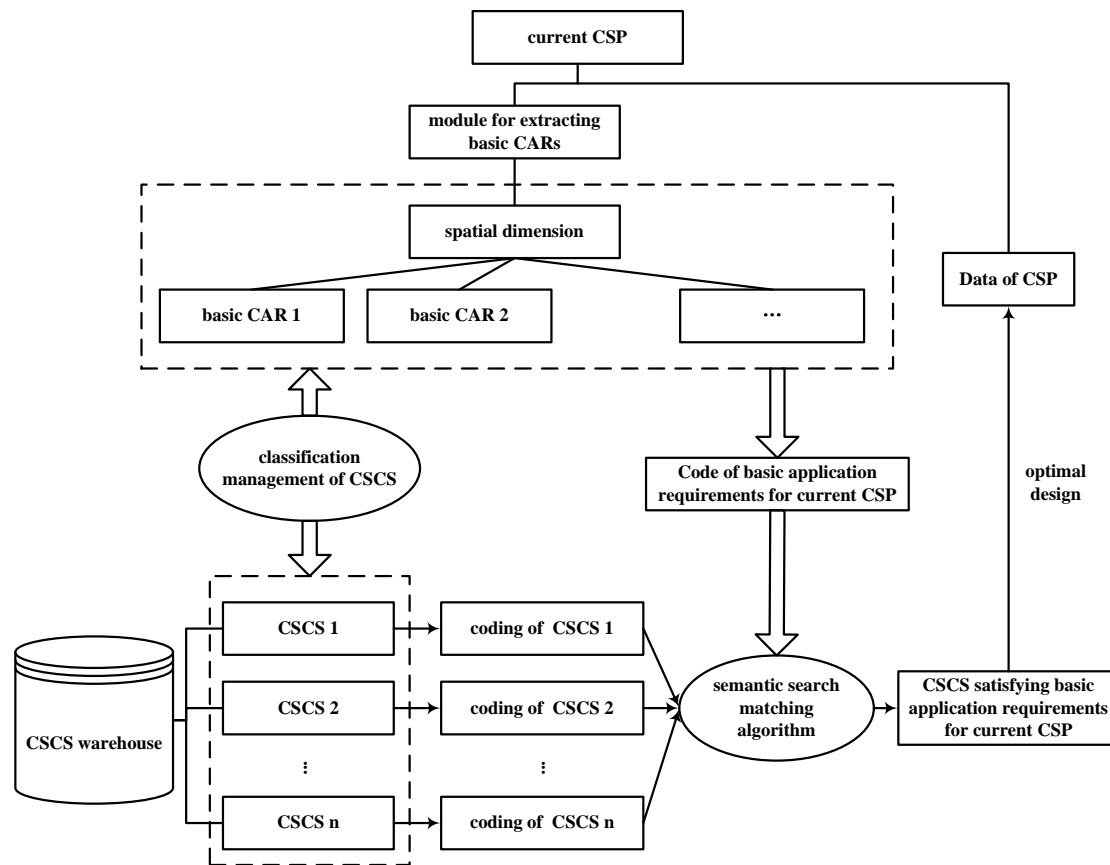


Fig. 5 The flow chart figure of search matching of CSCS

The current CSP from user's cutting stock task consists of two parts: basic application requirement and data of CSP. The code of basic application requirement is based on the classification management of CSCS. The semantic retrieval technology based on ontology is used to search and match the suitable CSCS for basic application requirement, and apply them to deal with data of current CSP.

(3) Dynamic scheduling of CSCS

In order to improve the scheduling efficiency of the whole service platform and respond quickly to the cutting stock task submitted by the user, it is necessary to study the dynamic scheduling technology of CSCS in the platform. A service flow scheduling strategy based on multi-QoS demand

[10, 11] is proposed in cloud manufacturing environment. The flow chart of scheduling CSCS is shown in Fig. 6.

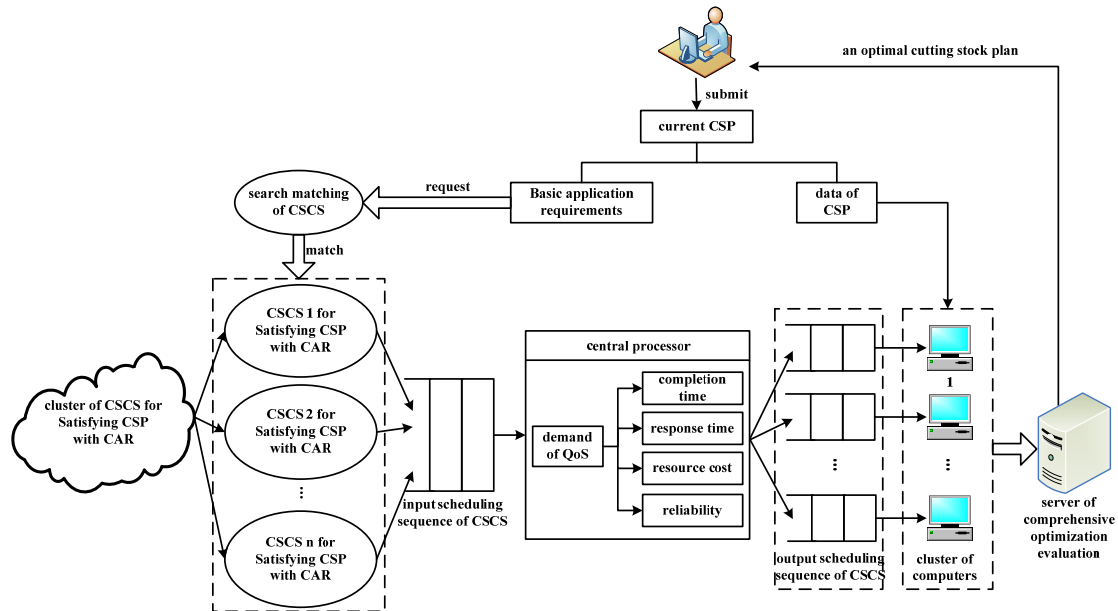


Fig. 6 The flow chart figure of dynamic scheduling of CSCS

The cluster of CSCS for satisfying CSP with CAR is obtained by search matching of CSCS. With the rule of first in first out, each CSCS in this cluster is put into input scheduling sequence of CSCS, and is quantitative analysis with demand of QoS in central process. The CSCS is distributed to each idle computer for optimization. By analyzed with a server of comprehensive optimization evaluation, an optimal cutting stock plan is achieved to return back to the current user.

4. Prototype System of this Service Platform

In order to verify feasibility of the above theoretical research and key technologies, the authors initially have built a prototype system for the service platform of cutting stock system in the cloud manufacturing environment on the basis of existing research on cutting stock system and networked manufacturing. Based on the combination of basic application requirements selected by the platform users, the system can call the matching a variety of suitable CSCS to optimize data provided by the current user, so as to meet the diversified needs of platform users. Some of the functional interface screenshots are shown in Fig. 7.

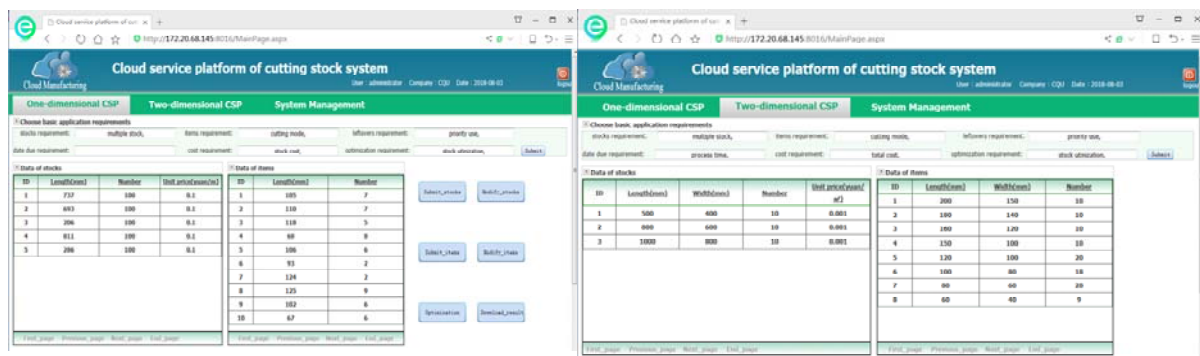


Fig. 7 Functional interface screenshots of prototype system for the service platform

5. Conclusion

In order to solve that single optimization algorithm cannot adapt to the CSP with CARs, this paper proposes an optimization method for CSP with CARs in cloud manufacturing environment. The authors sort CARs based on space and time dimensions during cutting stock process, and introduce method design for CSP with CARs. A cloud manufacturing service platform of cutting stock system is constructed by combining the common cloud manufacturing service platform and the existing traditional cutting stock system. In this platform, three key technologies that include classification management of CSCS, search matching of CSCS and dynamic scheduling of CSCS are presented detailedly. The classification management of CSCS is used to realize classification for CSCS in the CSCS warehouse. The search matching of CSCS is applied to select possible CSCS for current CSP. The dynamic scheduling of CSCS is used to distribute the selected CSCS to idle computer. Users can achieve an optimal cutting stock plan according to comprehensive optimization evaluation. Finally, the basic framework of the prototype system is presented to verify the feasibility of the proposed method for CSP with CARs.

Acknowledgments

This work was financially supported by National Natural Science Foundation of China, under Contract No.51575071.

References

- [1] Jia Z. State-of-the-art and future trends of cutting and packing studies [J]. *Journal of Computer-Aided Design & Computer Graphics*, 2004, 16 (7): 890-897.
- [2] Yan C, Song T and Liu F. Manufacturability-oriented one-dimensional cutting-stock problem under complex constraints status [J]. *Computer Integrated Manufacturing Systems*, 2010, 16 (1): 195-201.
- [3] Qin B, Yan C, Wang K, et al. Group optimization method of large-scale parts supporting centralized cutting stock [J]. *Computer Integrated Manufacturing Systems*, 2012, 18 (5): 943-949.
- [4] Cui Y, Zhong C and Yao Y. Pattern-set generation algorithm for the one-dimensional cutting stock problem with setup cost [J]. *European Journal of Operational Research*, 2015, 243 (2): 540-546.
- [5] Reinertsen H, Vossen T.W.M. The one-dimensional cutting stock problem with due dates [J]. *European Journal of Operational Research*, 2010, 201 (3): 701-711.
- [6] Li B, Zhang L, Wang S, et al. Cloud manufacturing: a new service-oriented networked manufacturing model [J]. *Computer Integrated Manufacturing Systems*, 2010, 16 (1): 1-7.
- [7] Yin C, Huang B, Liu F, et al. Common key technology system of cloud manufacturing service platform for small and medium enterprises [J]. *Computer Integrated Manufacturing Systems*, 2011, 17 (3): 495-503.
- [8] Wang J, Zhang Y and Li N. Research and Implementation of Semantic Retrieval Technology Based on Ontology [J]. *Computer Technology and Development*, 2009, 19 (10): 134-137.
- [9] Wu J, Wu Z, Li Y, et al. Web Service discovery based on ontology and similarity of words [J]. *Chinese Journal of Computers*, 2005, 28 (4): 595-602.
- [10] Chu Y, Ma T and Zhao L. Cloud Computing Resource Scheduling: Policy and Algorithm [J]. *Computer Science*, 2013, 40 (11): 8-13.
- [11] Sun D, Chang G, Li F, et al. Optimizing multi-dimensional QoS cloud resource scheduling by immune clonal with preference [J]. *Acta Electronica Sinica*, 2011, 39 (8): 1824-1831.