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Constraints Based Equipment Scheduling for Innovation Talent Cultivation in Chinese IT Undergraduate Education

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Abstract: Innovation talent is very important when working for information technology. Innovation talent cultivation is regarded as the first priority program during the Information Technology (IT) undergraduate education in Chinese universities. However, such program couldn't cover all the undergraduates all the time due to the insufficient equipment, instructors and investment. This study clarified the instructors, undergraduates, equipment and talent cultivation program with E-CARGO collaborative model and proposed an equipment scheduling algorithm based on the constraints. Algorithms are presented to identify the lack of equipment and optimize the equipment on demand. The results from the practice show that the suggested approach is objective and efficient.

Key words: Collaborative education, multiple attributes decision-making, project-based talent cultivation, equipment request conflict

INTRODUCTION

Innovation is a primary task of university and many countries including China to promote innovation talent cultivation in their universities (Akarsu, 2011). Innovation talent cultivation for undergraduate students is being paid special attentions by the experts in post-graduate education as well the employers who wish to employ some graduated university students with innovation awareness so as to fulfill difficult jobs (Chen and Feng, 2006; Xiang, 2007; Saran *et al*., 2009).

The undergraduates in Information Technology (IT) domain are required to have plenty of innovation awareness as they must master many new skills and knowledge, work on many different technique platforms and business domains (Xue and Feng, 2006; Xie *et al*., 2007) and handle lots complicated and large scale software development tasks (Changchien *et al*., 2002; Mahar, 2003; Shen *et al*., 2011; Tioh *et al*., 2012; Xu *et al*., 2012).

However, many universities do not have enough equipment, instructors and investment to cultivate the innovation of undergraduates (Yu *et al*., 2009). Due to the limitation of equipment and budget, they have to support only those important research projects and the post-graduate education. Undergraduate education has to be put in low priority and the equipment for such additional education turn out to be less sufficient. Meanwhile, there always lack the instructors to work on innovation talent cultivation for undergraduate students. How to achieve highly efficient innovation cultivation in IT undergraduate education with insufficient equipment, instructors and investment is an important issue to be solved.

Zhejiang Gongshang University is a large university located in Hangzhou, China. College of Computer Science and Information Engineering is one of the largest colleges in the University and there are around 2000 undergraduate students in the college. In order to bring up as many as possible excellent graduates, the faculty in the college has promoted innovation talent cultivation in undergraduate education for several years. This study, introduced some practices for the undergraduate innovation talent cultivation program. Considering the constraints of budget, equipment and instructors are still there, this study classified the relationship of the undergraduates, post-graduate students, faculty and equipment with a collaborative model and then proposed a constraints-based method to schedule the equipment so as to obtain the most achievement in innovation talent cultivation.

MOTIVATIONS

This study performed some online education with Moodle-based E-learning system (Xu, 2008a, b, 2009) while open source software Moodle is used to build the online Co-Learning system (Xu, 2008b), the reflection

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is evaluated on the basis of hyperlinks analysis (Xu, 2009) and learning action is analyzed with some pre-defined knowledge (Xu, 2008a). The practice of master student talent development is suggested to be collaborative implemented (Pan and Xu, 2010).

Involving master student in software projects or even Research and Development (R and D) process is an efficient approach for their talent development (Tu *et al*., 2005), of course they should master some fundamental concept and skill before joining a large project.

Collaboration is essential for those students involved in software projects and several researches have been done to facilitate the collaboration, including the Environments, Classes, Agents, Roles, Groups and Objects (E-CARGO) model proposed by Zhu (2006a) and Zhu and Zhou (2006). Zhu and Zhou (2008) proposed related approaches to support multi-agent system and role transfer as well. E-CARGO can be used in Service Oriented Architecture (SOA) architecture and it may facilitate the coupling decomposition significantly (Xu *et al*., 2008). E-CARGO has been used in modeling some collaboration systems, for example, in establishing a talent development system for master student education (Pan and Xu, 2010).

In this research, E-CARGO model is adopted to identify the relationship between the students, faculty, equipment and projects. Based on the relationship identification, the constraints can then be clarified so that we may design related algorithms to deal with the constraints and optimize the student projects to achieve the most fruitful innovation talent cultivation.

E-CARGO RELATED DEFINITIONS

E-cargo model: A role-based collaboration model, which named E-CARGO, is introduced by Zhu (2006a,b) and Zhu and Zhou (2006) to recognize the development/business environment as a role net. Each role provides a set of services and applies a few of services in the proposed net. E-CARGO is helpful to build a more efficient collaborative system, e.g., roles can be regarded as agent dynamics in multi-agent systems (Zhu, 2007). Role transfer in emergency management systems and related solution has been proposed in Zhu and Zhou (2008), which is also a regular activity in education management and can be adopted in resource replacement when there is lack of some key resource.

There are kinds of relationships in collaborative talent cultivation program for undergraduate students, including the relationships among students, between students and mentors, between different mentors and among R and D groups, equipment and projects. According to the E-CARGO model, all the personnel can be modeled as agents, positions such as student, professor, technician and staff can be modeled as roles and the tasks in R and D projects can be modeled as services, the equipment can be modeled as class/object data.

Related definitions: There are kinds of relationships in innovation talent cultivation for undergraduate education, including the relationships among students, between students and instructors, between different instructors and among innovation teams, equipment and projects. According, to the E-CARGO model, all the personnel can be modeled as agents, positions (student, professor, technician, staff) can be modeled as roles and innovation projects can be modeled as services, the equipment can be modeled as class/object data. The detail definitions are provided as follows:

Definition 1: Role. A role is the service template. A role is defined as r:: = <id, ca, av, S> ,where:

- id is the identification of the role r
- ca is the catalog of role, there are six different roles considered in this research work, including committee members, instructors, laboratory staff, master students, senior undergraduate students and junior ones
- av is the available time role r should contribute to the innovation projects
- S is a set of services provided by role r

As shown in Table 1, there are committee members, instructors, laboratory staff, master students, senior undergraduate students and junior undergraduate students.

Table 1: Roles and responsibilities for innovation cultivation in nndergraduate education

Role	Responsibility
Committee members	Coordinate the program and Approve the innovation projects.
Instructors	Apply an innovation project, Instruct the innovation team, Provide advice, or Provide technique support
Laboratory staff	Manage equipment
Master students	Provide direct technique instruction, Gather the status of innovation team and report to the instructors Verify and validate the research work
Senior undergraduate students	Participate the innovation project Finish the research work Write innovation report
Junior undergraduate students	Learn from the senior undergraduate students and master students to fulfill the innovation work

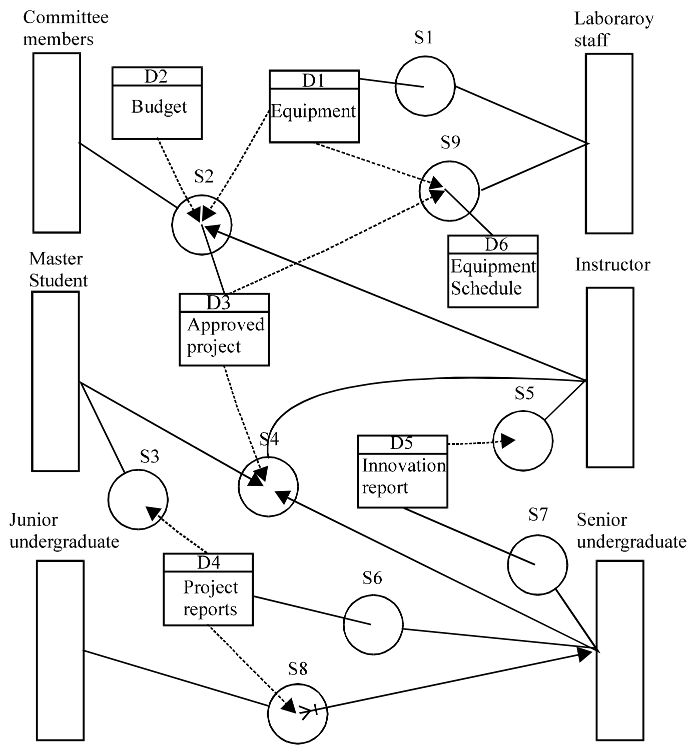

Fig. 1: Role net in undergraduate innovation talent cultivation program

Innovation cultivation is taken as an innovation project and each project contain several instructors to serve as the instructors, who is to provide advice and technique support when the team is in trouble, laboratory staff who provide equipment for the innovation work, a team with master students, senior undergraduate students and some junior undergraduate students. The graduate students will serve as daily instructors and provide direct and detail technique instruction to the team and they will gather and check the status of the innovation, verify and validate the innovation work. The senior undergraduate students are the major part in the innovation team; they should finish the research tasks, conduct the analysis, write software programs and finish the innovation reports. The junior ones will learn the methods, tools and other knowledge or skills from the senior ones or master students, which will benefit their future work.

All these people's positions can be modeled as roles in the E-CARGO model and the related responsibilities can be modeled as services.

Definition 2

Agent: An agent is a role player (i.e., people). It can refer to a profession teacher or students and it is defined as ag:: = <id, name, rid, av>, where:

- id is the identification of the agent ag
- name is the name of the agent ag
- rid is the role the agent belong to
- av refers to the total available time of agent ag may contribute to the innovation projects

Definition 3

Service: A service is a responsibility of a role. A service is a responsibility of a role. It is defined as s::=<id, r, input, output, target_role> where:

- id is the identification of the service
- r is the role who provide the service
- input refers to the input data set
- output refers to the output data set

Target_role refer to the target role which current role will be transferred to

As demonstrated in Table 1 and Fig. 1, there are six roles in this research, include committee member, laboratory staff, instructor, master student, senior undergraduate and junior undergraduate student. Mainly, there are 9 services provided by the related roles and there are 6 data objects are produced by the service or referred within the service. S8 is a special service which is used to transfer the role "Junior undergraduate" to the role "Senior Undergraduate". Table 2 shows a detail description of services provided by the roles defined in Table 1.

Table 2: Services provided by the roles

Service	From Role (to Role)	In	Out	To
S1: Record the equipment (mgt work)	Laboratory staff		D1	
S2: Evaluate and approve the projects	Committee member	D1, D2,	D3	
S3: Review the project reports	Master	D4		
S4: Recruit team members	Instructor	D3		
S5: Performance review	Instructor	D5		
S6: Implement project task	Senior undergraduate		D4	
S7: Summarize innovation achievements	Senior undergraduate		D5	
S8: Learning from the previous projects	Jnnior nndergraduate	D4		Senior nndergraduate
S9: Equipment scheduling	Laboratory staff	D1, D3	D6	

Definition 4

Project: A project is a special service, which refers to the collaboration of roles and equipment. However, in this research, project is the data object and used to model the approved projects. It is defined as pr::=<id, Rpt, E, P, v> where:

- id is the identification of the innovation project pr
- Rpt is a set of roles of the innovation project
- E is a set of equipment used in the innovation project
- P is the plan of the innovation project, as matched pair of the date, role, equipment and period, it is defined as p = {<d, r, e, period>}, which express assign the role r, equipment e at the period on date d. Period can be a serial of number indicating the available time of the equipment. For instance, 1, 2 and 8 can be used to refer to the first, second and eighth hours during the working time
- v is the value of the project, which is determined by the experts and the committee members

Definition 5

Facility: Facility is the catalog of equipment, such as computer, projector and network router, which is used in innovation research work. It is defined as fc:: = <id, name, co>, where:

- id is the identification of the facility fc
- name is the catalog of equipment, for instance, name can be linux-PC, windows-PC and projector
- co is the cost of the facility fc for a certain period

Definition 6

Equipment: Equipment can be computer, project or some other facilities which is used in innovation research work. It is defined as em:: = <id, fid, loc, avm, st> where:

- id is the identification of the equipment em
- fid is the identification of its catalog of em
- loc is the location of the equipment
- avm is a matrix of the available time of equipment, it is defined as {<d, period>}, indicating that equipment em is available at the period on date d
- st is the installation status of the equipment em, it can be fixed or removable

Definition 7

Talent cultivation system: The innovation talent cultivation system can be defined as tds=<ROLES, AGENTS, SERVICES, FACILITIES, EQUIPMENT, PROJECTS>, where ROLES refer to all the positions, AGENTS refer to all involved personnel, FACILITIES refer to all the equipment catalogs, EQUIPMENT refer to all equipment and PROJECTS refer to all innovation projects.

CONSTRAINTS AND RELATED PROBLEM SOLVING ALGORITHMS

During the innovation talent cultivation for undergraduate students, the equipment is limited and should be optimized for best realization of the talent cultivation goals. The committee should coordinate the program and make decisions for the project applications. As a result, the committee should make sure that there is no equipment usage conflict in these innovation projects and remove the conflict as much and as early as possible. Equipment usage conflict happens when certain equipment is applied by different projects at the same time or when two kinds of fixed equipment with different locations are applied by a certain project at the same time. This study is to check such equipment usage conflict and remove the conflict as much as possible based on the E-CARGO model.

Before the conflict checking, we should make sure if the equipment are sufficient for all the innovation projects. Those projects waiting for un-ready equipment have to obtain the similar equipment in the order of their value to innovation cultivation. A project lacking equipment should be postponed until the equipment conflict is resolved.

ALGORITHM FOR EQUIPMENT USAGE SUMMARIZATION

Before, identifying the conflict in the equipment usage, the equipment usage is better to be summarized. Here is the algorithm for the usage summarization.

Algorithm 1: Equipment Usage Summarization Algorithm

```
Input: EQUIPMENT, PROJECTS; INFRAusage = ϕ;// PROJECTS is the projects to be handled; EQUIPMENT is the equipment can be used
Output: INFRAusage contains a set of facilities usage in the projects
FOR(each ieq in EQUIPMENT) {//equipment ieq
infraid = ieq. facilities_id ()
FOR (each av in ieq.avm)
INFRAusage.add (infraid, av.d,av.period)
}
FOR (each ipr in PROJECTS) {//project ipr
FOR (each plan in ipr.P) {//plan as <d,r,e,period>
IF(plan.equipmentspecified)//equipment has been    specified.
infraid = plan.e. facilities_id(); //Method facilities_id is used to get facilities id.
ELSE infraid =plan.e.id
FOR (each usage in INFRAusage)
        If((usage.id=infraid) AND (usage.d=plan.d)) {
        usage.projects.add(ipr);
        FOR (each hour in period) { //period is a set of hours
        usage.vol.add(hour);
        usage.av.add(hour);
```

Algorithm 1 is used to summarize the equipment usage for all the innovation cultivation projects. The usage is calculated on the base of facilities; as a result, if equipment has been specified in the plan will also be traced back to its catalog. Equipment conflict checking will be performed on the bases of usage summarization.

ALGORITHM FOR EQUIPMENT CONFLICT CHECKING

There are two constraints for the equipment usage. One is that, the project could only apply for the available equipment anytime. Another is that, any equipment could not be overused (more than the available amount), as demonstrated in next constraints.

$$\begin{gathered}\forall eq \in \text{Equipment,date,period} \;\; \exists eq \in \text{usage}(\text{date,period}), \text{only if available}(eq,\text{date,period}) \\ \forall eq \in \text{Equipment,date,period} \;\; \sum \text{usage}(eq,\text{date,period}) <= \sum \text{available}(eq,\text{date,period})\end{gathered} \tag{1}$$

The following algorithm intends to check the possible equipment conflict from the usage.

Algorithm 2: Equipment Conflict Checking Algorithm

```
Input: EQUIPMENT, PROJECTS; INFRAusage; Pconflict=ô; Pinvalid=ô; // PROJECTS is the projects to be handled; EQUIPMENT is the equipment can be applied and used; Pconflict is a set of projects lack of equipment; Pinvalid contains those projects requiring for unavailable equipment; INFRAusage contains a set of facilities usage in the projects.
Output: Pconflict indicates the conflict of equipment usage, Pinvalid indicate the invalid usage of equipment.
FOR (each usage in INFRAusage) {
FOR (each hour in period)
IF ((usage.av&hour=0) AND (usage.vol&hour>0))
Pinvalid.add (usage.projects)
FOR (each hour in period)
sIF((usage.av&hour>0) AND (usage.vol&hour> usage.av&hour))
Pconflict.add (usage.projects)
}
```

Algorithm 2 is used to find out all the innovation projects may have conflict in equipment usage. The Pinvalid shows all the projects has required for unavailable equipment and Pconflict shows there are some possible conflicts between different innovation projects, indicating there will be some conflict removal that should be done to make appropriate decision.

ALGORITHM FOR EQUIPMENT CONFLICT REMOVAL

The goal of the innovation cultivation program is to improve the innovation talent of undergraduates as much as possible. As a result, the goal of the equipment scheduling is to find out the best solution to enlarge the benefit of these projects from the innovation talent cultivation. The value (which is evaluated by the committee members towards each projects during the project approval stage) is one important criterion to make the decision and here is the algorithm for the equipment usage conflict removal.

Algorithm 3: Equipment Conflict Removal Algorithm

```
Input: EQUIPMENT, PROJECTS; INFRAusage; Pconflict; Pinvalid; Psacrificed=ô; // PROJECTS is the projects to be handled; EQUIPMENT is the equipment can be applied and used; Pconflict is a set of projects lack of equipment; Pinvalid contains those projects requiring for unavailable equipment; INFRAusage contains a set of facilities usage in the projects.
Output: Psacrificed indicate the products to be ignored.
FOR(each ipr in Pinvalid) {
Pconflict.remove(ipr)
Psacrificed.add(ipr)
}
FOR (each ipr in Psacrificed) {//project ipr
FOR(each plan in ipr.P) {//plan as <d,r,e,period>
IF(plan.equipmentspecified) //equipment has been    specified.
infraid = plan.e.facilities_id(); //Method facilities_id        is used to get facilities id.
ELSE infraid =plan.e.id
FOR(each usage in INFRAusage) {
IF((usage.id=infraid) AND (usage.d=plan.d)) {
usage.projects.remove(ipr);
FOR(each hour in period) { //period is a set of hours
                usage.vol.delete(hour)
                usage.av.delete(hour)
                }
}
        }
}
//sort the Pconflict so as to improve the performance.
//The project with least iunovation value will be sacrificed at first.
Sort the Pconflict in the order of innovation value;
FOR (each usage in INFRAusage)
FOR (each hour in period)
IF (usage.vol&hour> usage.av&hour)
FOR (each ipr in Pconflict)
FOR (each ipr2 in usage.projects)
IF(ipr=ipr2) {
Pconflict.remove(ipr);
Psacrificed.add(ipr);
        FOR(each plan in ipr.P) {
        IF(plan.equipmentspecified)
        infraid = plan.e.facilities_id();
```

```
        ELSE infraid =plan.e.id;
        FOR (each us2 in INFRAusage)
                IF ((us2.id=infraid) AND (us2.d=plan.d))
        us2. projects.remove(ipr);
        FOR (each h in plan.period) {
                                us2.av.delete(h);
                                us2.vol.delete(h);
                }
        }//FOR(each plan..
}//IF(ipr=ipr2)
```

Algorithm 3 removes the possible conflicts by ignoring the innovation projects with low innovation cultivation value. It removes all the usage from the invalid project plan and then move out the usage of low cultivation value. Though, the coverage of the innovation talent cultivation will be reduced, the value of the talent cultivation will be improved with such decision. Pconflict is sorted in the order of innovation value.

DISCUSSION

A protocol of the above algorithms has been implemented and several simulations have been made. The results showed that the algorithms are good most of the time. Some instructors suggested sorting the projects in the priority of Return on Investment (ROI) (value/cost), so as to enlarge the total ROI of the innovation talent cultivation program. In practice, the cost of the equipment can be defined in two ways. One is to define the cost by the purchase price for each unit. It's simple and easy to operate, but it's not good to reduce the conflicts while some equipment with conflicts is of low purchase price. Another one is to dynamically define the cost according to the conflict status. For example, to define the equipment with more conflicts with higher cost and those units without conflicts can be defined as zero cost.

With each definition of cost, there could be a puzzle in the following scenario. Assume there are 3 projects (values at 5000, 6000 and 4000) are in the conflict on the same date and same period. The equipment usage of these projects is shown in Table 3. The date and period fields are ignored in the table.

There are two conflicts in this scenario, one is between Prj 1 and Prj 2 when requesting Eq. 1 and another is between Prj 2 and Prj 3 when requesting Eq. 3. Ideally, we may choose the Prj 1 and Prj 3 and scarify Prj 2 to achieve the higher value. However, it's really hard to define the cost so as to obtain the ideal solution.

Table 3: Puzzle in the equipment scheduling

Project usage	Eq. 1 (available 3)	Eq. 2 (available 8)	Eq. 3 (available 7)
Prj 1 (5000)	Request 2	Request 4	
Prj 2 (6000)	Request 2		Request 4
Prj 3 (4000)		Request 4	Request 4

The puzzle stated is not similar as the operating system scheduling, as we need to consider more options such as the kinds of equipment, installation type (fixed or not), project plan, innovation talent cultivation value and the related instructors and undergraduates. Fortunately, the equipment scheduling can be run in loops when there are some scarified projects and the related instructors still have the expectation to direct it. These instructors may view the conflicts and adjust the project plan accordingly.

CONCLUSION

Equipment conflict issue is introduced in innovation talent cultivation for undergraduate students with the constraint of equipment. A research is being conducted to adopt E-CARGO model to check the equipment conflict and remove the conflict by scarifying some low innovation value. In this study, E-CARGO model is briefly introduced and the definitions of the relationship in the innovation talent cultivation program have been presented. The algorithms to summarize the equipment usage, check the conflicts of equipment usage and remove conflict have been proposed. The simulations have been analyzed and the practice of the suggested algorithms and equipment scheduling has been suggested.

Currently, we are developing a framework with the involved algorithms to facilitate the innovation talent cultivation in our college. The benefit and weakness of the framework and related algorithms may be analyzed during the practice and will be improved or optimized accordingly.

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REFERENCES

Akarsu, B., 2011. Instructional designs in quantum physics: A critical review of research. Asian J. Applied Sci., 4: 112-118.

Changchien, S.W., J.J. Shen and T.Y. Lin, 2002. A preliminary correctness evaluation model of object-oriented software based on UML. J. Applied Sci., 2: 356-365.

Chen, N. and B.Q. Feng, 2006. An integration customer-driven requirement-refining scheme of business process reengineering. Inform. Technol. J., 5: 1113-1116.

Mahar, F., 2003. Information technology for management and decision supports systems. Inform. Technol. J., 2: 58-60.

Pan, L. and B. Xu, 2010. Towards collaborative master student talent development with E-CARGO model. Inform. Technol. J., 9: 1031-1037.

Saran, A., L. Serviere and M. Kalliny, 2009. Corporate culture, organizational dynamics and implementation of innovations: A conceptual framework. Asian J. Market., 2: 10-19.

Shen, W.H., N.L. Hsueh and P.H. Chu, 2011. Measurement-based software process modeling. J. Software Eng., 5: 20-37.

Tioh, J.W., V. Nathan, M. Mani, R.J. Weber and A.K. Somani, 2012. Reconfigurable high-speed platform: Shifting the paradigm in education, research and engineering. IEEE Commun. Mag., 50: 153-159.

Tu, Q., K.L. Wang and Q. Shu, 2005. Computer-related technostress in China. Commun. ACM, 48: 77-81.

Xiang, H.F., 2007. Cultivating innovative talents through reforming engineering education. Struct. Eng. Int., 17: 209-209.

Xie, Z., S. Wang, D. Zhang, F.L. Chung and Hanbin, 2007. Image segmentation using the enhanced possibilistic clustering method. Inform. Technol. J., 6: 541-546.

Xu, B., 2008a. Constructing online co-learning system for computer technology education using open source package Proceedings of the 2008 International Symposium on Information Science and Engineering, December 20-22, 2008, Shanghai, pp: 219-223.

Xu, B., 2008b. Knowledge based learning action analysis in online Co-learning. Proceedings of the 2nd International Symposium on Intelligent Information Technology Application, December 20-22, 2008, Shanghai, pp: 162-166.

Xu, B., 2009. Reflection evaluation in online e-learning system via hyperlinks analysis. Proceedings of the 4th International Conference on Computer Science and Education, July 25-28, 2009, Nanning, China, pp: 1673-1677.

Xu, B., M. Chen, C. Liu, J. Li, Q. Zhu and A.J. Kavs, 2012. Enabling continuous quality improvement with quantitative evaluation in incremental financial software development. Inform. Technol. J., 11: 76-84.

Xu, B., X.H. Yang, Y.H. Shen, S.P. Li and A. Ma, 2008. A role-based SOA architecture for community support systems. Proceedings of the International Symposium on Collaborative Technologies and Systems, May 19-23, 2008, Irvine, CA, USA., pp: 408-415.

Xue, L. and B. Feng, 2006. A model-driven approach for business constraints discovery. Inform. Technol. J., 5: 454-459.

Yu, B., B. Xu, Y. Ling and H. Zhu, 2009. Equipment conflict checking and removal for innovation talent development in IT undergraduate education via E-CARGO collaborative model. Proceedings of the 4th International Conference on Computer Science and Education, July 25-28, 2009, Nanning, China, pp: 1669-1672.

Zhu, H. and M.C. Zhou, 2006. Role-based Collaboration and its Kernel Mechanisms. IEEE Trans. Syst. Man. Cybern. C., 36: 578-589.

Zhu, H. and M.C. Zhou, 2008. Role transfer problems and algorithms. IEEE Trans. Syst. Man. Cybern. A., 38: 1442-1450.

Zhu, H., 2006a. A role-based approach to robot agent team design. Proceedings of the IEEE International Conference on Systems, Man and Cybernetics, October 8-11, 2006, Taipei, China, pp: 4861-4866.

Zhu, H., 2006b. Role mechanisms in collaborative systems. Int. J. Prod. Res., 41: 181-193.

Zhu, H., 2007. Role as dynamics of agents in multi-agent systems. Syst. Inform. Sci. Notes, 1: 165-171.