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ORIGINAL ARTICLE

Cloud computing in human resource management (HRM) system for small and medium enterprises (SMEs)

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Abstract Enterprise systems consist of numerous integrated applications including manufacturing, logistics, distribution, accounting, marketing, finance, human resources, and others. Enterprise system is intended to enable automation as it offers the availability of real-time data, improved process visibility, and an increased level of automation. In this paper, we propose to use cloud computing technologies to share computing resources and support advanced features such as on demand payments in human resource management (HRM) sub-system, and we focus on the applications in small and medium enterprises (SMEs). The presented work consists of the following four parts. First, we discuss the cloud computing concept extensively in terms of the definitions, the classifications, and main characteristics, as well as its applications. Second, we perform the game analysis on the cloud computing of HRM in SMEs. Third, we propose new infrastructure of cloud computing to implement HRM in SMEs. Fourth, we illustrate the applications of the proposed infrastructure in HRM; in particular, we discuss some cloud-computing-based enterprise systems application systems including *human resources management alliance*, *human resources management consulting services*, and *human resources shared services* for process reengineering. Our innovation is the primary attempt of applying cloud computing technologies to elevate HRM subsystem in enterprise systems for SMEs.

Keywords Cloud computing · Enterprise systems · Small and medium enterprises (SMEs) · Human resource management (HRM)

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1 Introduction

Due to the saturation of manufacturing capabilities and globalized business environments, small and medium-sized enterprises (SMEs) are struggling for some vital solutions for them to gain technical strengths over competitors [7, 8]. However, most of studies in manufacturing fields focused on the development of new hardware systems to achieve component-level automation or flexibility. For example, modular systems, reconfigurable machines, and parallel kinematic machines have been investigated to increase machines' capabilities in dealing with the variations of manufacturing processes [1, 3–6, 8, 9]. System-level enabling technologies have also been explored extensively by many researchers [27, 30–33, 35, 37, 38, 40]; however, most of existing works are limited to the development of information architectures within enterprises. There are some emerging needs for SMEs to take advantages of the rapidly developed information technologies (IT) to

design, operate, and improve their manufacturing systems [14, 17, 18, 27, 28, 32].

Enterprise systems consist of numerous integrated applications including manufacturing, logistics, distribution, accounting, marketing, finance, human resources, and others. Enterprise system is intended to enable automation as it offers the availability of real-time data, improved process visibility, and an increased level of automation [36]. Decision-making activities in a manufacturing system rely greatly on information systems. Emerging cloud computing technologies are proven as both of the opportunities and challenges to SMEs. As a new and powerful solution to store, access, and utilize data over the Internet, the cloud computing allows keeping a huge amount of data over clouds and provides superior computing capacities to lead the innovations in the development of information systems. However, cloud computing is still at its infant stage, its potential has yet been explored fully in different applications. Therefore, we have been highly motivated to adopt cloud computing technologies in human resource management (HRM) of enterprise systems for SMEs.

The rest of the paper is organized as follows. In Sect. 2, we review the concept of cloud computing briefly and we propose system architecture for cloud computing based services. In Sect. 3, we develop new infrastructure to implement HRM in SMEs based on cloud computing technologies. In Sect. 4, we illustrate some practical applications for HRM using the proposed infrastructure in HRM, which include *human resources management alliance*, *human resources management consulting services*, and *human resources shared services* for process reengineering. Finally, we summarize and conclude our work in Sect. 5.

2 Cloud computing

To develop vital and efficient information systems, SMEs can benefit greatly from cloud computing technologies to meet their technical challenges in updating and managing manufacturing resources dynamically [21, 25, 39]. Cloud-computing-based systems allow SMEs storing, accessing, and utilizing abundant data over clouds to improve the efficiencies of enterprise systems, reduce operational costs, and eventually achieve sustainability of manufacturing systems. In this paper, we focus on the application of cloud computing technologies in HRM. In contrast to large-scale enterprises or enterprise alliances, human resources at SMEs are relatively scarce and dynamic; it is critical to allocate human resources appropriately to warrant their business successes.

Despite of numerous development on cloud computing, there is no definition of cloud computing, which has been accepted unanimously by the academic society. Generally, *cloud computing* refers to the integration development and commercialization of advanced information technologies in *distributed computing*, *parallel computing*, *grid computing*, *network storage*, and large-scale data warehouses [11, 13, 29]. From the perspective of technology development, cloud computing is an integrated solution for users to deal with massive network resources. For examples, the system developers as users can build some cloud computing application systems to purchase or lease resources or services through the Internet [2, 33]. As shown in Fig. 1, cloud computing services can be classified into three types, i.e., *Infrastructure as a Service* (IaaS), *Platform as a Service* (PaaS), and *Software as a Service* (SaaS). From the perspective of targeted users, cloud computing can be classified according to the cloud types, i.e., *public cloud*, *private cloud*, *community cloud*, and *hybrid cloud*.

Cloud computing has been identified with the following main characteristics: (1) *sharing*. Cloud computing technologies support data access, exchange, and sharing for anyone, anytime, and anywhere; in comparison with conventional information technologies, cloud computing promotes team working and sharing of manufacturing resources across enterprises; (2) *Flexibility*. Cloud computing allows users to request services and obtain manufacturing resources at any location and at any time using a variety of personal assistant device (PAD) or computing terminals; (3) *Pay-as-you-go*. Cloud computing distributes manufacturing or service resources based on users' demands; users pay the platform or services based on the allocated resources with no waste. (4) *Low cost*. Large-scale enterprises can build their own cloud-based systems and highly utilize the systems to reduce cost of their information systems. For SMEs, they are able to use systems developed by major IT vendors such as Google, IBM, Amazon, and Microsoft. In the next section, we will conduct the game analysis to find what benefits the cloud computing technologies can bring to SMEs.

3 Game analysis

SMEs contribute to our society and economy greatly. Taking the USA as an example of developed countries, 99.7 % of US firms are classified as SMEs; these SMEs offer 64 % of net private-sector jobs [24]. The roles of SMEs to developing countries are similar. For example, numerous SMEs run their businesses in China, which have contributed significantly to stimulate economic growth, relieve employment pressure, and optimize the infrastructure of the national economy.

Due to the natures of SMEs, the manufacturing resources in SMEs are generally scarce, and the technologies for planning, controlling, or management are relatively lagged. This brings the challenges for SMEs to manage available manufacturing resources optimally. In particular, limited methodologies have been developed on human resource management (HRM), which are specifically applicable to SMEs. We are motivated

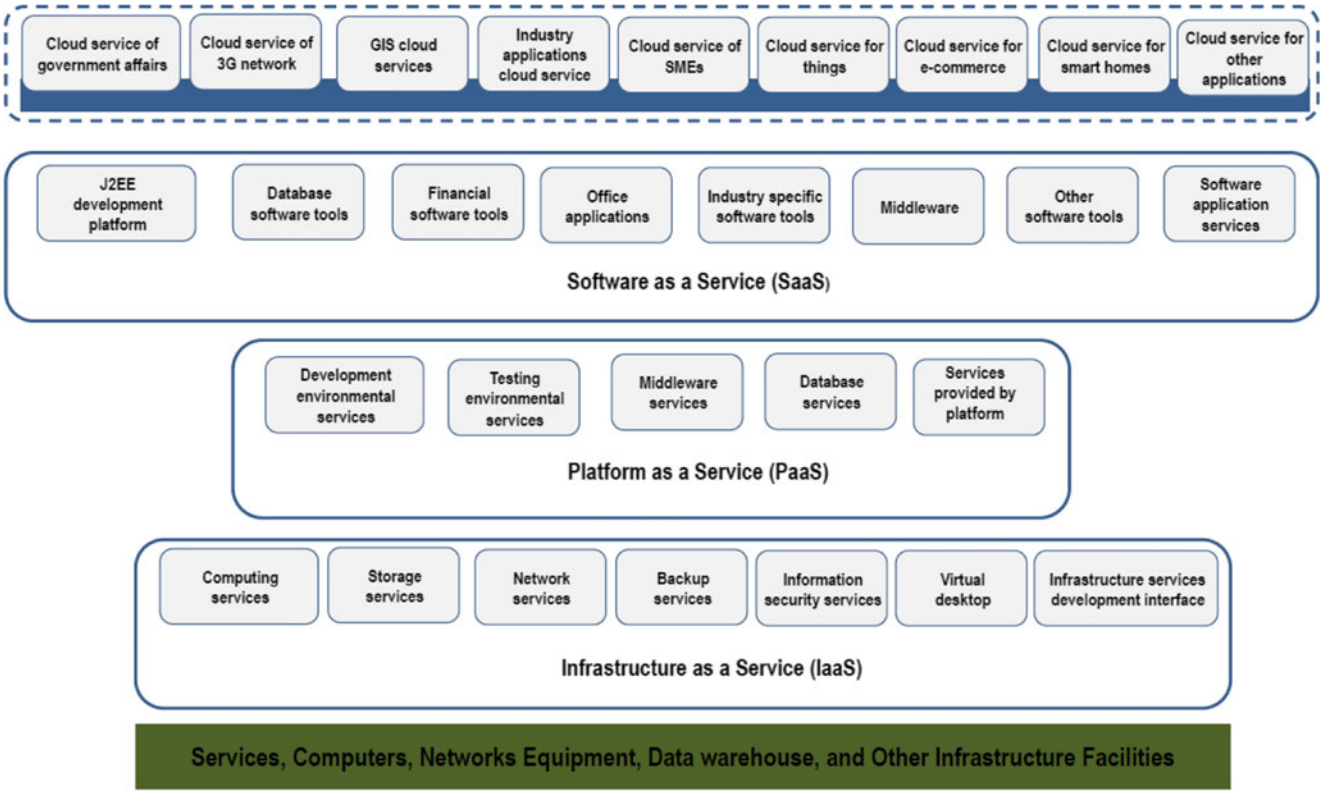

Fig. 1 Types of cloud-computing-based services

to address this issue, and we explore the feasibility of adopting rapidly developed cloud computing in HRM information systems of SMEs.

To allocate manufacturing resources appropriately, SMEs can handover partial or all non-core businesses to cloud service providers; they can run these businesses on behalf of SMEs with the minimized cost to SMEs.

Due to the presence of the asymmetric information in game processes,the SME users are incapable of supervising cloud service providers in cooperating and collaborating with SME customers and other service providers. If the outcomes produced by cloud service providers are measurable, there is no need for SME users to put extra effort in monitoring the operations of service providers. However, if the outcomes from provided services are unmeasurable, SMEs require software tools to supervise service providers to quantify the contributions for cloud service providers. However, it is difficult to perform the supervision in practices. The challenge to SME users is to ensure cloud service providers represent SMEs' best interests. The solution to this challenge is critical to smoothen the cooperation processes. In this section, the game theory is applied to analyze the relations of SME users and cloud services providers.

To apply the game theory, we assume that (1) both of SMEs and cloud services providers can be treated as rational economic men, and (2) SMEs can choose *supervising* or *no-supervising*, and cloud service providers can choose to be *exertion* or *inexertion*. Accordingly, the decision matrices for both players are shown in Table 1.

In Table 1, R represents the revenue of SMEs in the case that the cloud providers make their full efforts on behalf of SME users. r represents the revenue of SMEs in the case that the cloud providers make their partial efforts on behalf of SME users. W is the cost occurring to the delegated SMEs; it contributes to the revenue of the cloud service providers. C_1 stands for the supervising cost paid by SMEs; C_2 is the cost for services by cloud providers. L is the loss to SMEs when the cloud service providers do not make their best efforts. M is an additional benefit to SMEs from cloud service providers. F stands for the gained interests from the cloud service providers' punishment in case SMEs are aware of the inexertion of service providers. μ is the coefficient to measure the efficiency of the providers' efforts ($0 \le \mu \le 1$). μ is used by SMEs to determine the punishment of cloud service providers. Accordingly, service providers need to determine additional revenue from the inexertion on the services for of SMEs. Game analysis by decision matrices is performed as follows:

1. When $F + (1-\mu)L \le C_1$, it implies that the punishment on cloud service providers and irreparable damage is less than the cost for SMEs to monitor services providers. In this game, the best strategy is not dependent on policy choices by service providers for SMEs. No matter how service providers are chosen, the best option for SMEs is

Table 1 Game decision matrices of SMEs and cloud service providers

Side B / Side A		Cloud service providers	
		Exertion	Inexertion
SMEs' users	Supervising	$R-W-C_1, W-C_2$	$r-W-C_1+\mu F\text{-}L, W+\mu M\text{-}F$
	Non-supervising	$R-W, W-C_2$	$r-W-L, W+M$

not to supervise service providers. Under this circumstance, the supervising cost C_1 and C_2 could not be fully recovered.

2. When $F+(1-\mu)L>C_1$, the loss of SMEs by the service providers' inexertion can be compensated by the punishment applied on service providers. Under this circumstance, there is no pure strategy of Nash equilibrium. Let p be the probability that SMEs need supervising cloud service providers and q be the probability of cloud service providers for being exertions.

The parameter p is 1 and 0 for the cases when SMEs choose *supervising* and *non-supervising*, respectively. The expected returns are expressed as

$$\begin{aligned}\phi(1,q) &= (R-W-C_1)q+(r-W-C_1+F-\mu L)(1-q)\\ &= (R-r+F+\mu L)q+r-W-C_1+F-\mu L\end{aligned} \quad (1)$$

$$\begin{aligned}\phi(0,q) &= (R-W)q+(r-W-L)(1-q)\\ &= (R-r+L)\,q\,+\,r-W-L\end{aligned} \quad (2)$$

In the situation of the mixed strategy Nash equilibrium, SMEs expect the same benefits whether or not supervising is chosen. In this case, one finds $\varphi(1, q)=\varphi(0, q)$, i.e., $q=1-C_1/[F+(1-\mu)L]$. It indicates that the lower supervising cost is, the greater is the probability when the cloud service providers make their best efforts. Meanwhile, the greater the penalty and non-supervising loss is, and the greater is the probability when the cloud service providers make their best efforts. SMEs can achieve incentive compatibility constraint based on supervising cost and specified penalty.

The parameter q is 1 and 0 for the exertion and inexertion of service providers, respectively. The expected rewards for the cloud service providers can be represented by

$$\phi(p,1) = (W-C_2)p+(W-C_2)(1-p) = W-C_2 \quad (3)$$

$$\phi(p,0) = (W+\mu L-F)p+(W+M)(1-p) \quad (4)$$

In the case of the mixed strategy Nash equilibrium, expected rewards are the same for both of the exertion of inexertion, i.e., $\varphi(p, 1)=\varphi(p, 0)$. It leads to $p=(M+C_2)/(W+F-\mu L)$. The smaller cost of efforts by cloud service providers is, the lower is the probability that SMEs choose supervising. Meanwhile, the greater extra revenue from non-supervising is, the greater the probability of supervising is. Cloud service providers are responsible to make their own decisions by considering both of incurred cost and extra benefits.

Despite of the fact that cloud computing technologies have been advanced greatly, continuous efforts are demanding to improve cloud computing. SMEs have the options to select cloud services and supervise cloud service providers based on their own interests. On the other hand, cloud service providers must enhance their technical competence to meet the critical needs from SMEs to achieve sustainability of their businesses in a long-term.

4 System architecture

Cloud computing technologies can be applied in developing human resource management (HRM) information systems for SMEs. Under the unified cloud platform, cloud computing allows SMEs to access various services quickly and safely. Figure 2 shows the conceptual model of a cloud-computing-based information system. SMEs can use various mediums over the Internet to request services provided by cloud service providers.

As shown in Fig. 2, an HRM information system consists of *cloud service providers*, *HRM users*, and *cloud service platforms* (middleware). Cloud service providers offer SMEs with a variety of resources, solutions, and cloud services. Via the cloud platform of the information system, service

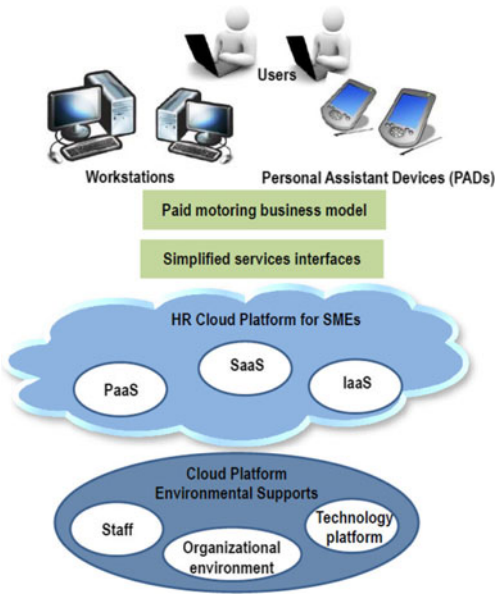

Fig. 2 Cloud computing HRM information systems of SMEs

providers give SMEs with a wide range of cloud services to meet the requests from SMEs. SMEs can request specific services based on their own demands; in addition, different SMEs can share human resources over the platform.

The runtime environment of the cloud platform consists of three key elements, i.e., (1) *the personnel* as service users and providers; (2) *the organizational environment* with operational safeguards; and (3) *the technology platform* or system such as the relations illustrated in Fig. 3.

To implement cloud-computing-based information system, existing cloud computing platform and technologies are integrated to provide HRM services, and an overview of the integrated information system is illustrated in Fig. 4. The architecture of information system consists of six layers from higher to lower ones as follows: *user access layer*, *interaction layer*, *transport layer*, *software as a service* (SaaS) *layer*, *Platform as a Service* (PaaS) *layer*, and *Infrastructure as a Service* (IaaS) *layer*. The information system can invoke resources based on demand from top to bottom layers, and SME customers request services from the bottom layer. As a whole, the information system provides all services for SMEs including technical supports, shared services, HRM, consulting services, and other accessory services [42].

5 Case study applications

In this section, we introduce a few of critical sub-system in the proposed HRM information system for SMEs to illustrate the feasibility of the proposed technical solutions for SMEs in cloud-computing-based HRM.

5.1 Cloud-computing-based HRM alliance

Cloud computing will bring technological innovations in the sense that manufacturing resources can be shared across SMEs; this can be achieved by developing a platform for the cooperation and collaboration of SMEs. The cloud-computing-based platform for resource sharing is proposed and illustrated in Fig. 5. In this illustration, the HRM alliance consists of three SMEs (in reality, an alliance can have an arbitrary large number of SMEs; three SME members in Fig. 3 are for the simplification of description). For each SME, its information system includes *individual private clouds*, *main public cloud*, and hybrid clouds; these clouds are integrated into the platform of HRM alliance. The alliance platform is responsible for the high-level supervision and the management of various clouds to facilitate cooperation and collaboration in the alliance across SMEs.

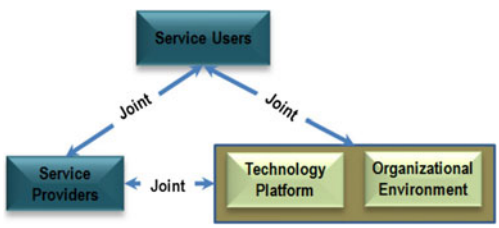

Fig. 3 Relationship of three key elements

5.1.1 Private clouds

Private clouds are built by individual users in one SME, and they are treated as private users in the cooperative platform of SMEs. The management and allocation of internal human resources fall in the scopes of responsibilities of private clouds. The cloud-based services for individual users can enhance the efficiency and reduce the cost of HRM. Through specific interfaces of the platforms, provider clouds can be connected to a public cloud to share data, transfer information, and archive data. Typical private clouds in a SME are clouds for *recruitment*, the clouds for *salary management*, and the clouds for trainings. Since private clouds are implemented on the Internet, SME users can access corresponding services conveniently by any devices connected to wired or wireless networks such as personal computers, workspaces, cell phones, and other mobile devices.

5.1.2 Public cloud

The public cloud is a public cloud developed to support the rapid growth of SMEs. The public cloud is usually developed by a third-party cloud service provider to customize the services for SME individuals; in turn, SMEs pay for the use of services. The public cloud is responsible of maintaining and upgrading the alliance platform, exchanges data among private clouds, and supports resource backup consolidation. Therefore, the public cloud achieves the effective usage of resources by reducing the redundancies and maintaining the consistencies of data and information. In the alliance's platform, the public cloud supports all types of cooperation and collaboration in new product development, project management, and manufacturing resources.

5.1.3 Hybrid clouds

The third type of clouds is hybrid clouds. A hybrid cloud not only possesses the characteristics of security and exclusiveness as private clouds but can also make the full use of resources integration and rational utilization to reduce costs as a public cloud. In the alliance's platform, hybrid clouds are developed based on the agreements of SMEs through communication and consultation among companies. Participating SMEs can select the information of manufacturing resources shared with others on hybrid clouds. After a hybrid cloud is established, participating SMEs have their responsibilities in updating the

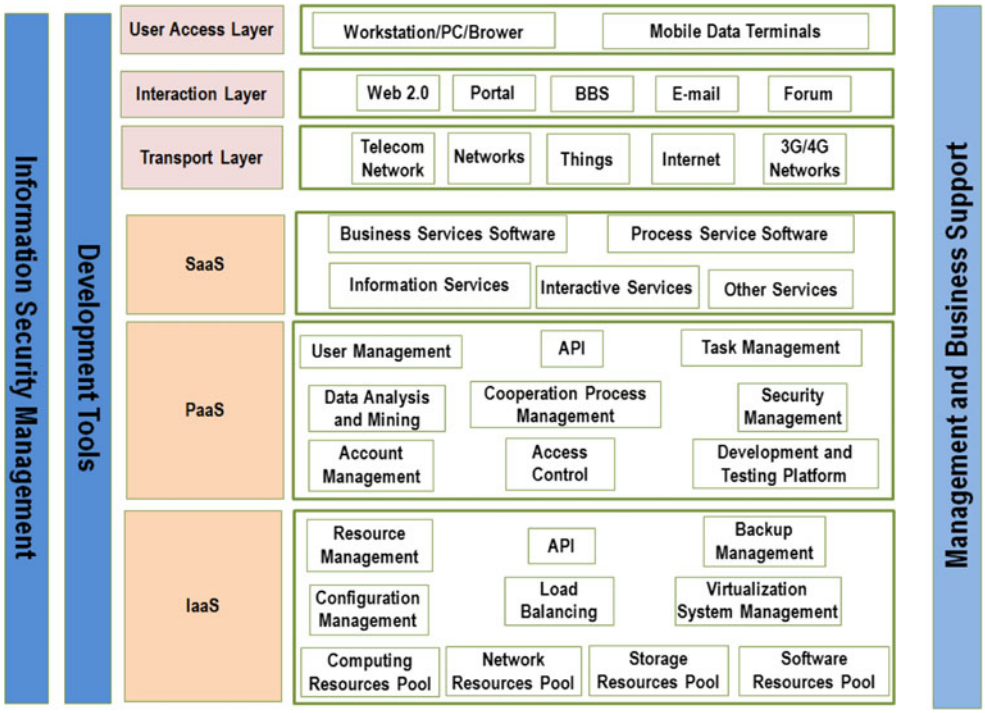

Fig. 4 Proposed HRM information system for SMEs

information of shared manufacturing resources timely to support the effective cooperation and collaboration of HRMs.

5.1.4 Cooperation and collaboration in alliance

As shown in Fig. 5, the alliance's platform is responsible to manage and oversee hybrid clouds, organize all kinds of resources, and secure the information of users over the Internet to enhance the performance of the HRM information system.

5.2 HRM consulting services

The aforementioned architecture can be applied for SMEs to access services from a broad scope over the Internet. Figure 6 has shown the framework for SMEs to access consulting services globally. In such a framework, the cloud computing technologies are used to support SMEs to access services from the communities such as the resources by experts in human resource management, advisory bodies, and internal and external stakeholders.

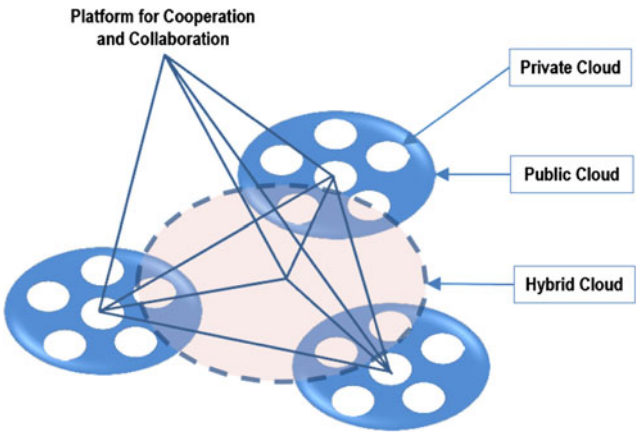

Fig. 5 Exemplifying platform for cooperation and collaboration in SMEs alliance

In such a framework, SMEs can access consulting services by terminals through the networks such as wired or wireless 3G networks. SMEs are able to communicate with external experts outside enterprises to obtain consulting services of HRM. In such a circumstance, consulting agencies are only required to invest a tiny portion of capital investment on the information infrastructure; they are not required to invest more in the maintenance of information systems. From this point of view, consulting agencies are becoming more and more willing in providing services over the Internet. Cloud computing technologies make it possible to access consulting services by any terminals connected to the Internets for HRM of SMEs.

The framework for HRM consulting services of SMEs can be treated as similar community networks such as Facebook and Twister. SMEs as user individuals can publish and share the information freely with other enterprises; it becomes tacit knowledge which can be grasped by users and converted into explicit knowledge. On the other hand, each SME communicates with other users in the community to respond to the demands from users in data exchanging and sharing. The framework in Fig. 6 can be used to develop a virtual community of SMEs dedicated to provide consulting services within the community. As far as the mechanisms of services are concerned, services can be on one-to-one, one-to-many, many-to-

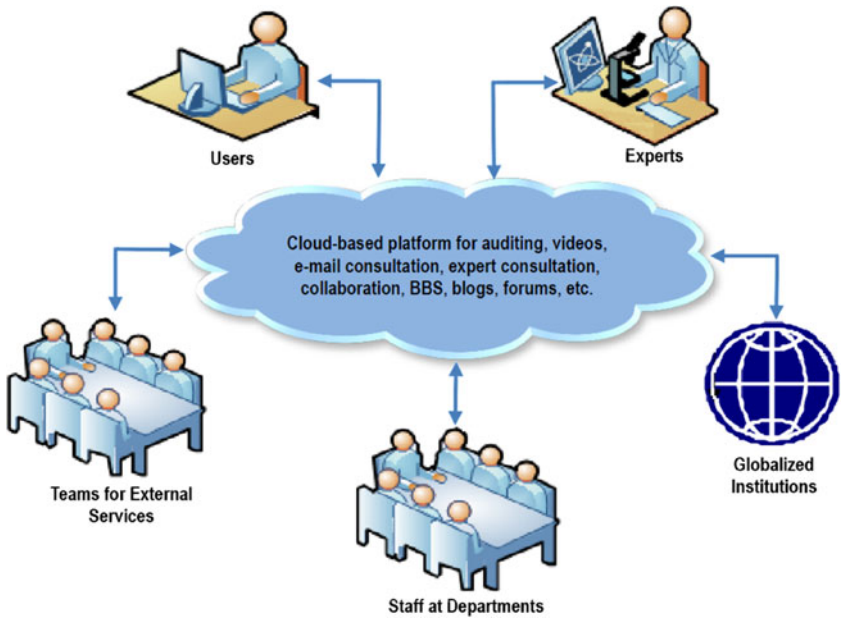

Fig. 6 System framework of HRM consulting services

one, and many-to-many bases; therefore, the variety of service mechanisms help SMEs in the community to achieve scale effect, which brings greater economic benefits for participating SME users.

5.3 Shared services for process reengineering of SMEs

The platform for cooperation and collaboration is generic and can be extended to share any services across the clouds among SMEs. Figure 7 shows an application system to share services for process reengineering of SMEs. This application system consists of three cirtical functional models, i.e., *human resources sharing center* (HRSSC), *business partners* (HRBP), and *human resources experts* (HRE) in the cloud platform.

A shared HMR platform of SMEs stimulates the revolution of the working processes. In the following, some anticipated revolutions of working processes for typical functions of a HRM information system are discussed.

5.3.1 Recruiting process

A recruiting process refers to the process in a SME to acquire specific human resources to meet its business needs. A cloud-computing-based information system can improve recruiting processes in multiple ways as follows.

First, the cloud-based technologies reserve the talented comprehensively and efficiently in the sense that the new HRM information system is capable of updating all information related to human resources promptly; this is very beneficial for SMEs to identify and contact appropriate candidates. It allows SMEs to communicate with applicants quickly and develop talents pools for future uses efficiently.

Second, the techniques for big data analytics can be applied in searching ideal candidates. With the abundant information over clouds, data mining can be performed in different catalogues such as employment histories, physical and mental health conditions, or personal and academic achievements. For example, the Talent Radar can analyze one's hobbies and profiles based on given criteria to assess potential candidates; it automatically identifies candidates who meet knowledge or skills requirements. By analyzing the profile of each applicant, the Talent Radar creates a map with the matrixes at different aspects such as professional backgrounds, friends, and personalities.

Third, the new recruiting system assesses candidates thoroughly based on the searching criteria. Technical competences are generally the most important qualifications for employees at certain job positions. Using the data from background search, interviews, questionnaires, and statistic analysis, SMEs can develop their models of competences. In the cloud-computing-based system, enterprise can collect abundant data about employees and organizations and utilize it to determine the required qualifications for best employees. The identified qualifications can be used as new standards to select and hire new employees.

Fourth, the recruiting process can be informatized. Conventional recruiting methods are usually based on a large volume of resumes, which have to be reviewed and judged by human experts. With an aid of cloud computing, SMEs can find the most wanted talents in a short time frame to reduce recruiting cost. The new recruiting process is shown in Fig. 8.

5.3.2 Training processes

Training processes are essential means for SMEs to meet their strategic development needs by improving knowledge and

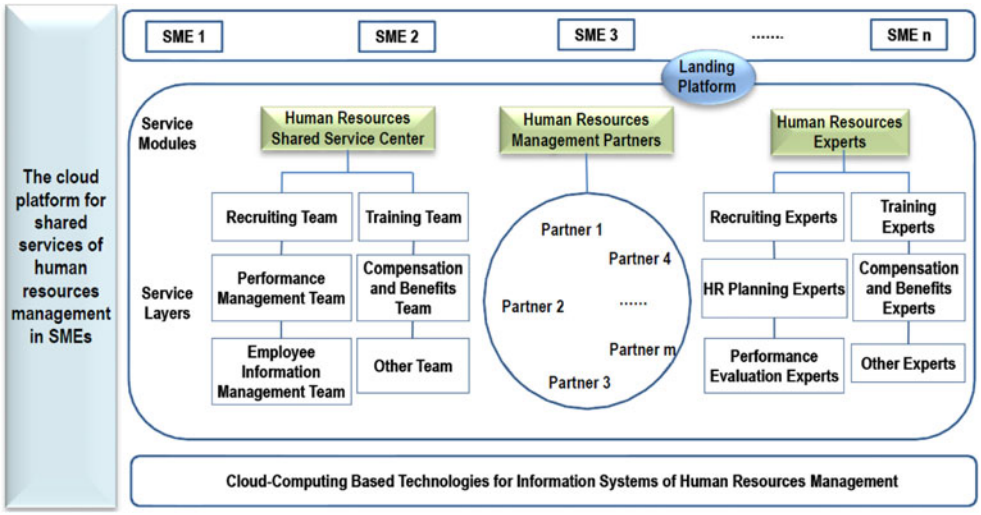

Fig. 7 Architecture of HRM shared services

skills of employees, exploring their potentials to perform their responsibilities efficiently.

First, enterprises make their plans for training and broadcast the news to inform relevant employees and staff. Employees make their training schedules to upgrade their knowledge and skills such as business knowledge, communication skills, management skills, or certificates of using commercial software tools. For the most of training programs, employees can access training in either of full-time or part-time bases, and they can attend trainings onsite or remotely in the cloud-computing-based information system.

Second, SMEs can outsource training programs. The Internet provides the connections to a variety of professional institutions for SMEs to request training services; those institutions are able to customize the training programs to specific needs from SMEs. On the other hand, training institutions take advantage of the cloud-based platform to share the resources of training experts, methods, and techniques.

Third, the planning and scheduling of employee training and career development can be significantly simplified in the sense that SMEs can utilize abundant data in the system to assess the performances of employees and develop the model of qualifications in mapping the required skills to available job positions. Using the developed model, enterprise can tailor employees' training and development plans to the required qualifications at work. A training process in new information system is shown in Fig. 9.

5.3.3 Performance management

The performance management covers all of functionalities within the business department of a SME. These

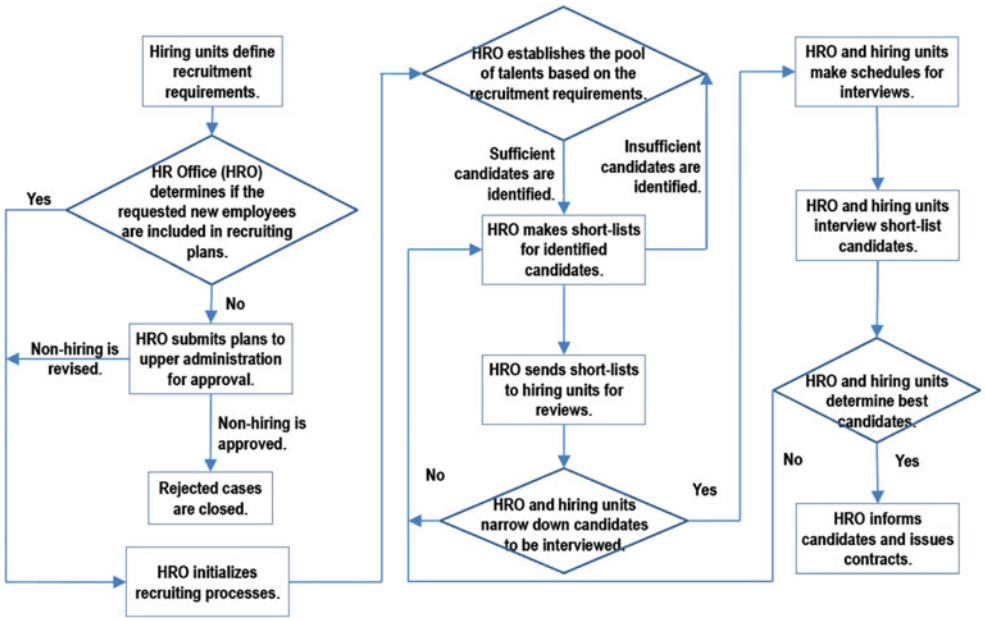

Fig. 8 New recruiting process

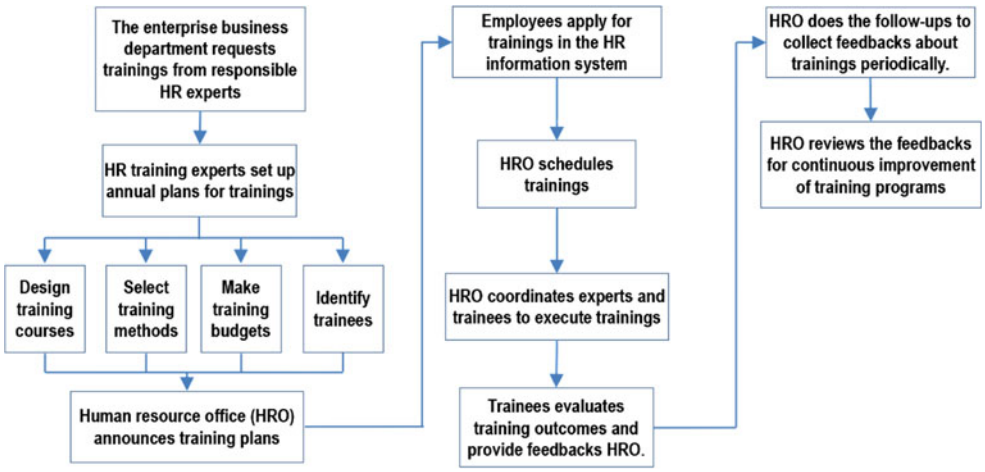

Fig. 9 New training process

functionalities include making performance evaluation indices, defining scales, and collecting and analyzing data. The performance management also includes digitizing of the performance management business such as collecting inspection data or appraisal results. To quantify the strategies of SMEs, the performance management also provides quality indicators for assessments of employees.

First, an enterprise needs to select the tools for the performance assessment. The system for the performance management can match the levels or the characteristics of employees to the features of the performance assessment tools automatically. Based on the identities of inspected targets, the system will select the competitive tools for the performance evaluation. For example, the performance evaluation tools such as *the 360° evaluation method*, *the critical performance indicator method*, and *the critical incident method* can be selected and used for employees in different job categories.

Second, an enterprise applies the selected tools to evaluate the performances of processes. A conventional HRM system serves mainly as data storages. The integration of cloud computing technologies expands the functionalities of an HRM information system in that sense that it helps in the standardization of the management processes. In particular, in the process of performance evaluation, the enterprise can use the *key performance indicator method* (KPI) to decompose strategic targets into a set of sub-evaluation indices. This makes possible to update and evaluate key parameters related to the internal work processes of a SME. With an integration of the data from the performance evaluation, the proposed system can analyze data systematically for continuous improvement of the information system. With the automatic mapping of cloud computing services, the performance management process can be more systematic and standardized. The illustration of the performance management in the proposed information system is shown in Fig. 10.

5.3.4 Compensation management

Compensation management refers to a dynamic management process where the principles, allocations, and structures of compensation are determined. Compensation management follows the guidance of organizational development strategies.

First, SMEs are able to compute compensations and benefits conveniently using the cloud-computing-based system. The system is equipped with many assistive functions related to compensations such as statistical analysis and allocation of compensations. The system compiles the model dictionary and the digital dictionary with the structured technology; it makes possible to sort the data related to the compensations of employees rapidly and effectively. For example, if a SME issues a new compensation plan, the system can respond to it immediately together with other existing compensation policies. In addition, the system supports the self-services for employees to promote paperless logistics in SMEs.

Second, the cloud-based system analyzes data of compensations and benefits systematically. The proposed system possesses many versatile and powerful functional modules to meet analytical needs of compensation data for SMEs. In particular, the cloud computing technologies use the distributed storage mode. This satisfies the needs of SMEs to store and access data in distributed manufacturing environment.

Third, SMEs can use a specific type of cloud as "the cloud for compensation." The cloud for compensation can be viewed as a part of "the cloud for human resources management." The cloud for compensation provides more flexibility for employees to take actions and collaborations. For example, a SME can create new posts other than traditional ones, which makes transboundary collaborations of different posts feasible. The cloud for compensation includes all types of incentive resources to employees. For example, flexible incentive programs can be included for a SME to reward employees with the excellence in working ethics, productivities, and

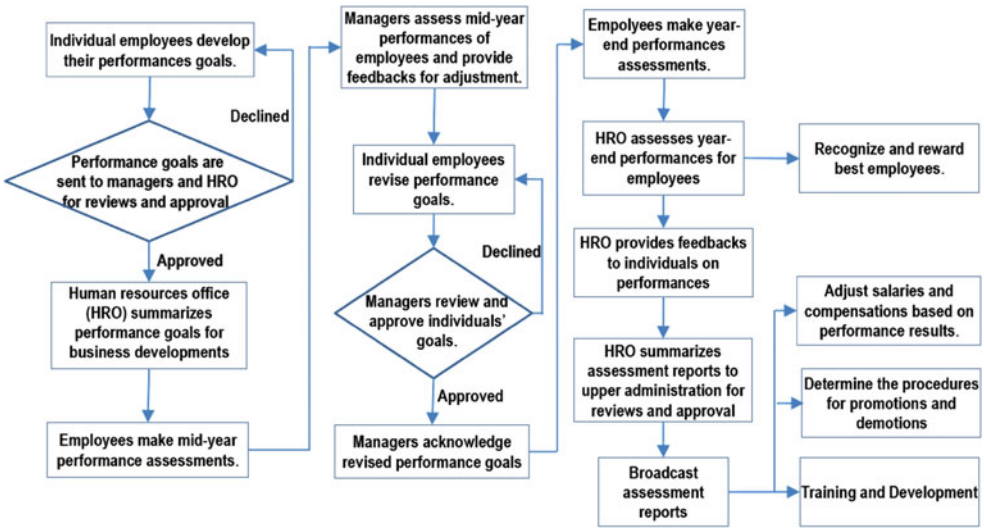

Fig. 10 New performance management process

innovations. The process of new compensation management is shown in Fig. 11.

6 The application of cloud-based human resource management in automotive enterprise

Due to the features of interconnection, interoperability, and collaboration, cloud-based human resource management can solve enterprise's problems such as the conflict between regular workers and temporary contractors, the resource limitation in space and management, and multi-batches running in series et al.

In open and innovative environment, it is common that automobile enterprises and their R&D contractors integrate external technical resources and capabilities to reduce development costs and enhance development speed. Currently about 40 % of the parts are designed through outsourcing including creative car styling design, components reverse engineering, and parts production outsourcing.

Under traditional model, automobile enterprises need to hire large number of designers to design each module after receiving design tasks. However, it is usually carried out only by 30–40 designers for hundreds of component, due to the limitation of space and budget. It takes about 3–4 months for multi-batches running in series.

Cloud-based human resources and organizational model eliminate limitations such as the number of workers and distribution, through online crowd sourcing, parallel design, and a virtual enterprise including OEMs, suppliers, research and development contractors, and large number of contract designers. With detailed tasks break down and virtual enterprise

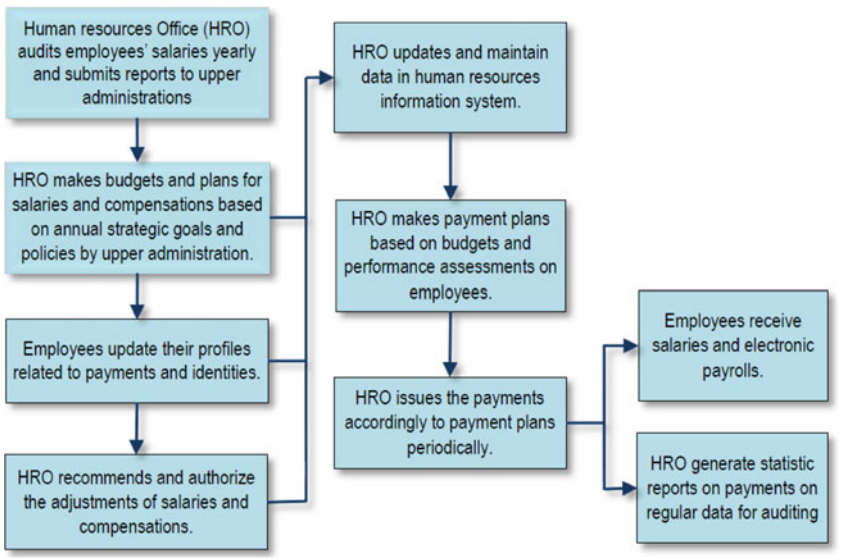

Fig. 11 New compensation management process

online recruiting, it is possible that many certified designers could design auto parts through cloud manufacturing platform distribution, parallel design, and real-time communication. As the result, the design cycle could be significantly shortened to 1–2 months.

Major progress has been made regarding R&D model, such as the use of virtual rapid prototyping technology and 3D printing technology to create rapid prototypes, the transition from the traditional serial, centralized way to the network-based parallel, distributed model. The web crowdsourcing for designer breaks through enterprise resource capacity bottlenecks and improves the overall complex product development T, Q, C. Under traditional centralized management model, the cost of travel and review meeting takes up to more than 70 % of the total design cost, with time cost of more than 50 % of the total cycle. In contrast, under cloud computing model, 80 % saving of the assessment cost and more than 60 % saving on communication time could be achieved by using collaborative R&D methods, collaborative design based on full 3D digital prototype. New methods such as those that could use cloud distribution of resources, collaborative design, virtual assembly test mode, 3D model online browsing, and tagging are available for designers.

Regarding manufacturing model, enterprises are used to invest millions for purchasing of CNC machine, CATIA/Alias software, and other large engineering hardware and software. Under smart manufacturing mode, personalized online 3D printing, large-scale software engineering, and other manufacturing cloud services, online rental services are available in accordance with the needs of automotive research and development. With conventional production prototyping, equipment purchase of 100 million or more is required, plus 2 to 3 weeks of programming time, while under smart manufacturing mode, 1:8 prototyping, by using online 3D printing service, could be completed within 1 day, with rental and material total costs only a few million.

7 Summary and conclusions

SMEs are facing various technical challenges in managing human resources due to the scarce of information, technologies, and management expertise. A potential vital solution is to take advantage of emerging cloud computing technologies. Cloud computing has been regarded as the fourth revolution in information technology (IT) [15, 19, 22, 43]. Together with big data, cloud computing brings numerous opportunities for the innovations in a broad scope of industrial applications ([10, 12, 16, 20, 23, 26, 33, 34, 41]). In this paper, we proposed to adopt cloud computing technologies in the enterprise systems of SMEs for human resources management. We developed the system architecture and framework for such systems, and we discussed main system components as well as their relations. In addition, we developed three application systems for human resources managements in SMEs to illustrate the feasibility and significance in using cloud computing technologies in HRM information systems.

The proposed information system not only enhances the system performances of traditional HRM activities but also expands the system capabilities in terms of its flexibility to deal with uncertainties and changes and making HRM processes standardized. Adopting cloud computing technologies will radically change the concepts and methodologies used in traditional management practices. With the proposed system, SMEs are able to take advantage of modern management tools and standardize business processes and, eventually, enhance the performance of human resources management in cost reduction and system efficiency. The proposed architecture has shown that using cloud computing technologies requires the platform to support resources sharing and on demand services. Our discussions on the prototyping systems suggest that it is important for SMEs to standardize HRM practices, so that available tools and methods for cloud computing can be utilized optimally. The proposed system allows SMEs to request cloud services flexibly to meet their business needs; cloud service providers can customize HRM services to meet specific requirements of SMEs. Note that the reported work is limited to our preliminary study on integrating cloud computing in HRM for SMEs; our focus in the near future is to implement actual systems and apply in SMEs.

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References

1. Bi ZM (2010) Computer integrated reconfigurable experimental platform from ergonomic study of vehicle body design. Int J Comput Integr Manuf 23(11):968–978
2. Bi ZM (2014) Kinetostatic modelling of exechon parallel kinematic machine for stiffness analysis. Int J Adv Manuf Technol 71(2014): 325–335
3. Bi ZM, Kang B (2010) Enhancement of adaptability of parallel kinematic machines with an adjustable platform. ASME J Manuf Sci Eng 132(9) doi: 10.1115/1.4003120
4. Bi ZM, Lang SYT, Verner M, Orban P (2008) Development of reconfigurable machines. Int J Adv Manuf Technol 39(11–12): 1227–1251
5. Bi ZM, Lang SYT, Verner M (2008) Dynamic modeling and validation of a tripod-based machine tool. Int J Adv Manuf Technol 37(3–4):410–421
6. Bi ZM, Liu Y, Baumgartner B, Culver E, Sorokin N, Peters A, Cox B, Hunnicutt J, Yurek J, O'Shaughnessey S (2015) Reusing

industrial robots to achieve sustainability in small and medium-sized enterprises (SMEs). Int J Ind Robot 42(3):264–273
7. Bi ZM, Pomalaza-Raez C, Singh Z, Nicolette-Baker A, Pettit B, Heckley C (2014) Reconfiguring machines to achieve system adaptability and sustainability: a practical case study. Proc Inst Mech Eng Part B-J Eng Manuf 228:1676–1688
8. Bi ZM, Xu LD, Wang C (2014) Internet of things for enterprise systems of modern manufacturing. IEEE Trans Ind Inform 10(2): 1537–1546. doi:10.1109/TII.2014.2300338
9. Bi ZM, Zhang WJ (2001) Modularity technology in manufacturing: taxonomy and issues. Int J Adv Manuf Technol 18(5):381–390
10. Branger J, Pang Z (2015) From automated home to sustainable, healthy and manufacturing home: a new story enabled by the Internet-of-Things and Industry 4.0. J Manag Analytics 2(4):314–332
11. Cao Y (2014) The research of the problem about the intellectual property rights of cloud computing. Sci Tech Prog Countermeasures 5(9):136–142
12. Cheng Y, Tao F, Liu Y, Zhao D, Zhang L, Xu L (2013) Energy-aware resource service scheduling based on utility evaluation in cloud manufacturing system. J Eng Manuf 227(12):1901–1915
13. Dai F, Sun B, Long C (2011) The applied research of cloud computing in the informatization construction of SMEs. Jiangsu Bus Theory 2011(06):62–64
14. He W, Xu L (2015) A state-of-the-art survey of cloud manufacturing. Int J Comput Integr Manuf 28(3):239–250
15. He W, Yan G, Xu L (2014) Developing vehicular data cloud services in the IoT environment. IEEE Trans Ind Inform 10(2):1587–1595
16. Hu W, Hou Y, Tian L, Li Y (2015) Selection of logistics distribution center for SDN enterprises. J Manag Analytics 2(3):202–215
17. Huang L (2012b) The application of competitive intelligence service based on cloud computing. Master's Thesis, NanKai University, Tianjing, China
18. Huang W (2012) The application of Cloud computing in the informatization of SMEs. Study Sci Technol Manag 2012(6): 185–187
19. Jiang L, Xu L, Cai H, Jiang Z (2014) An IoT oriented data storage framework in cloud computing platform. IEEE Trans Ind Inform 10(2):1443–1451
20. Jin C, Li F, Willamowska-Korsak M, Li L, Fu L (2014) BSP-GA: a new genetic algorithm for system optimization and excellent schema selection. Syst Res Behav Sci 31(3):337–352
21. Li G (2012) The system design and implementation of human resources in a small and medium-sized enterprise. Master's Thesis of Huazhong University of Science and Technology, Wuhan, China
22. Li S, Xu L, Wang X, Wang J (2012) Integration of hybrid wireless networks in cloud services oriented enterprise information systems. Enterp Inf Syst 6(2):165–187
23. Liu X, He W, Xu L, Yan G (2014) Enhancing the security of cloud manufacturing by restricting resource access. J Homel Secur Emerg Manag 11(4):533–554
24. SBA (2012) Advocacy: the Voice of Small Business in Government, https://www.sba.gov/sites/default/files/FAQ_Sept_2012.pdf
25. Shi M (2011) The research of the building of shared service center of human resources of enterprise C. Master's Thesis, Shanghai Jiao Tong University, Shanghai, China
26. Tan W, Chen S, Li J, Li L, Wang T, Hu X (2014) A trust evaluation model for e-learning systems. Syst Res Behav Sci 31(3):353–365
27. Tao F, Cheng Y, Xu LD, Zhang L, Li BH (2014) CCIoT-CMfg: cloud computing and Internet of Things-based cloud manufacturing service systems. IEEE Trans Ind Inform 10(2):1435–1442
28. Tao F, LaiLi Y, Xu L, Zhang L (2013) FC-PACO-RM: a parallel method for service composition optimal-selection in cloud manufacturing system. IEEE Trans Ind Informatics 9(4):2023–2033
29. Tao F, Zhang L, Liu Y, Cheng Y, Wang L, Xu X (2015) Manufacturing service management in cloud manufacturing: overview and future research directions. J Manuf Sci Eng 137(4): 040912
30. Tao F, Zhang L, Venkatesh VC, Luo Y, Cheng Y (2011) Cloud manufacturing: a computing and service-oriented manufacturing model. J Eng Manuf 225(10):1969–1976
31. Tao F, Zhao D, Hu Y, Zhou Z (2008) Resource service composition and its optimal-section based on particle swarm optimization in manufacturing grid system. IEEE Trans Ind Inform 4(4):315–327
32. Tao F, Zuo Y, Xu LD, Zhang L (2014) IoT-based intelligent perception and access of manufacturing resources toward cloud manufacturing. IEEE Trans Ind Inform 10(2):1547–1557
33. Wang C, Bi Z, Xu L (2014) IoT and cloud computing in automation of assembly modeling systems. IEEE Trans Ind Inform 10(2): 1426–1434
34. Xie Y, Takala J, Liu Y, Chen Y (2015) A combinatorial optimization model for enterprise patent transfer. Inf Technol Manag 16(4): 327–337
35. Xu L (2011) Enterprise systems: state-of-the-art and future trends. IEEE Trans Ind Inform 7(4):630–640
36. Xu L (2015) Enterprise integration and information architectures. CRC Press, Taylor & Francis Group
37. Xu L, Liang N, Gao Q (2008) An integrated approach for agricultural ecosystem management. IEEE Trans SMC Part C 38(4):590–599
38. Xu L, Wang C, Bi ZM, Yu J (2014) Object-oriented templates for automated assembly planning of complex products. IEEE Trans Autom Sci Eng 11(2):492–503
39. Yang L (2012) The research of process reengineering of human resource management in enterprise group based on the model of HR Shared service. Master's Thesis, Ocean University of China, Qingdao, China
40. Yang Y, Wang L, Wang Y, Bi ZM, Xu Y, Pan S (2014) Modeling and optimization of two-stage procurement in due-channel supply chain. Inf Technol Manag 15(2):109–118
41. Yu X, Nguyen B, Chen C, Li F (2014) Electronic CRM and perceptions of unfairness. Inf Technol Manag 16(4):351–362
42. Zhang F (2014) The research on SAAS model of human resource management system in China. Human Resour Manag 1:35–38
43. Zheng X, Martin P, Brohman K, Xu L (2014) CLOUDQUAL: a quality model for cloud services. IEEE Trans Ind Inform 10(2): 1527–1536