Guest Editorial
Advances of Systems Research in Service Industry

SERVICE industry has received increasing interest in recent years [1]–[3]. The economies in industrialized nations across the world have become more service oriented. The workforce employed in services continued to grow in developed economies during the second half of the 1980s and the 1990s. At the beginning of 2000, in several Organisation for Economic Co-operation and Development (OECD) countries, about three quarters of employees were working in the service sector [4]. In 2007, the world's biggest source of employment was, for the first time, the service sector, rather than agriculture and industry. About 40% of the world's workers were employed in the service sector, compared with 38.7% in agriculture and 21.3% in industry. About 18 years ago, 43.1% of employees worked in agriculture, and only 35.5% worked in the service sector. It was predicted that, in the future, the service sector would provide more than half of global employment opportunities [5].

It is obvious that services are playing a key role in today's global economy, and such trend can be expected to continue in the future. As a result, the importance of studying the service industry in systems perspectives has been increasing. A systems perspective can help better address the systems characteristics involved with service industries and possibly provide a framework which will foster the development of formal models of service systems.

Service industry is one of the most challenging sectors in industrial and economic development, and the new material flow theory which can be applied to the service sector has been proposed [6]–[10]. A variety of service industry paradigms have been developed to tackle the challenges [1], [2]. There are many research issues needed to be addressed using the methods including systems research; as such, a variety of systems models have been developed to tackle these challenges [11]–[26]. Today, not only large companies but also medium- or small-sized companies are learning that understanding service industries as well as their systems aspects is a required component of doing business. As a result, there is a growing demand for insights into challenges, issues, and solutions related to the systems methods in the service sector.

To respond to the market needs from both academic researchers and practitioners and to communicate research results on systems research in service industries, this special issue provides an international forum for researchers in academia and industry to present their most recent findings in systems research in service industries.

This special issue of *IEEE Systems Journal* presents 11 papers. The purpose of this special issue is to report on the state of the art of, and emerging trends in, research and practice in systems research in the service sector. To prepare for this issue, all authors were asked to respond to multiple rounds of peer review. Each paper emphasizes the importance of systems research in the service sector from a unique perspective.

Several developed nations around the world are grappling with high health-care expenditures and unsatisfactory outcomes. The U.S. health-care system in particular is often singled out as the least effective system among developed countries. In the paper by Fradinho *et al.* [27], the authors provide a system's perspective of health care beyond traditional high-level country benchmarking exercises and conduct two exploratory cases of leading hospital enterprises, one from the U.S. and another from the U.K., so as to further the understanding of the inherent complexity of hospitals. The authors also address a recent call from the systems engineering community to adopt a multidisciplinary research approach that combines both qualitative and quantitative methods with the goal of further supporting the systems-of-systems practice.

A series of research and practical findings on services has been achieved in existent disciplines; however, systems research on modern service systems is less discussed. In the survey paper by Wang *et al.* [28], the authors discuss and review the contribution and potentials of systems theory for service science, management, and engineering (SSME). Starting up with primary definitions on services and service systems, this paper sheds light on some systems issues in service science and engineering, service operations, and service systems management and makes a summary of theories or tools at systems level applied in services and service systems. Finally, some potential prospects in SSME research are presented as the conclusion.

In the paper entitled "On a unified definition of the service system: What is its identity" [29], the authors proposed a unified definition of the service system. The motivation of this effort is that there are diverse definitions or descriptions of the service system in the literature and they have not provided an identity of the service system. Their goal to define the service system is thus to establish its identity. The most salient feature in their definition is the introduction of three subsystems in a service system: infrastructure, substance, and management. The substance "flows" over the infrastructure under the constraints of management. A service is established at the moment that the substance interacts with the human to cause a change in the human's status or state under a protocol, which further meets the human's request and need. With this new definition, a service system can be distinguished from other systems, such as manufacturing system, agricultural system, and production

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system. The new definition will be useful to classification of various service systems and various theories for service systems, which is the key to knowledge management for service systems and to optimization of design and management of service systems.

Product line engineering has become the main method for achieving systematic software reuse. Embracing requirements in a product line's asset base enhances the effectiveness of reuse as engineers can work on the abstractions closer to the domain's initial concepts. Conventional proactive approaches to product line engineering cause excessive overhead when codifying the assets. In the paper by Niu *et al.* entitled "A Systems Approach to Product Line Requirements Reuse" [30], the authors propose a systems-oriented approach to extracting functional requirement profiles. The validated extraction constructs are amenable to semantic case analysis and orthogonal variability modeling, so as to uncover the variation structure and constraints. To evaluate the approach, the authors present an experiment to quantify the extraction overhead and effectiveness and a case study to assess their approach's usefulness. The results show that the automatic support offers an order-of-magnitude saving over the manual extraction effort without significantly compromising quality and that the approach receives a positive adoption rate by systems engineers.

In the paper by Lai *et al.* [31], the authors apply an adapted form of Hall's 3-D systems engineering methodology to develop a systematic framework for developing and implementing innovation in traditional food and beverage service industries. The platform improves the communication between the enterprise owner and the systems development team and enables the system to be systematically reviewed and amended as required in order to ensure that it meets its objectives and constraints. The development platform not only provides the means for a business to improve its current competitive edge by introducing innovation but also puts in place the mechanisms required to ensure its continuous improvement and brand development.

In designing and developing enterprise systems, systems engineers must consider the requirements that drive the important architecture decisions. Architecturally significant requirements tend to have a global impact on the underlying software infrastructure and therefore need to be thoroughly examined. Despite the increasing effort in engineering enterprise systems' requirements, little is known about the analysis of architecture interactions and tradeoffs. In the paper by Niu *et al.* [32], the authors propose a framework consisting of an integrated set of activities to help tackle requirement analysis in practice. Specifically, they leverage the quality attribute scenarios to elicit implicit yet significant requirements, to model requirement interplays, to manage terminological interferences, and to determine change impacts. They apply the proposed framework to a customer relationship management software system. The results show that the framework offers concrete insights and can be incorporated into an organization's systems practice with a moderate cost.

Path reliability, congestion, and energy consumption are three major constraints affecting routing in wireless sensor networks (WSNs). By considering the reliability, congestion control, and security for multipath, in the paper by Li *et al.* [33], a sensor-centric information routing scheme in sensor networks is proposed. In the scheme, an evaluation metric for path vacant ratio is proposed to evaluate and discover a link-disjoint path set for multipath load balancing from all available paths. Congestion control and load-balancing algorithm are provided which are able to adaptively adjust the load over multipath. In order to improve the robustness and reliability of paths, packets are transformed into multiple segments by a threshold sharing algorithm and delivered via multiple independent paths to the destination depending on the path vacant ratio. Simulation results show that the proposed scheme is more efficient in terms of reliability, end-to-end delay, data delivery ratio, and deadline miss ratio compared with the existing multipath routing protocols.

Cloud services have been utilized in large-scale distributed environments. As an effective service aggregation methodology, workflow technology has been used to construct composite services. Efficient and dependable workflow scheduling (WFS) is crucial for integrating enterprise systems. In the paper by Tan *et al.* [34], the authors propose a trust service-oriented WFS algorithm. The scheduling algorithm adopts a trust metric that combines direct and recommendation trust. In addition, the authors provide balance policies to enable users to balance different requirements including time, cost, and trust. A case study was conducted to illustrate the value of the proposed algorithm. The experimental results show that the proposed approach is effective and feasible.

Localization systems have been identified as a fundamental and key issue in WSNs, which enables location-aware applications that provide different types or levels of services based on the location information. In the paper by Li *et al.* [35], a distributed approach based on local semidefinite programming is proposed to solve the localization problem in large-scale WSNs. Extensive simulations demonstrate that the proposed method can achieve better scalability and higher accuracy and is also robust to the measurement noise.

Service-oriented architecture (SOA) is characterized by dynamic service discovery and composition. For user-centric SOA, not only services, workflows, and application templates can be published and discovered for composition. A key issue in user-centric service composition is to intelligently and effectively discover the subset of correlated services that best match the users' requirements. In the paper by Tsai *et al.* [36], the authors propose a two-step composition process. In the first step, users choose templates from ontology with its dependence. The dependence information identifies a set of candidate services and workflows that may be applicable for composition. In the second step, after the templates are selected, users can finalize the selection of services and workflows from a set of candidate services or workflows based on their preference. This two-step process is supported by dependence identification algorithms and is illustrated using a case study.

Most of telemedicine systems for long-term ECG monitoring focus on the application of communication techniques. However, how to monitor long-term ECG state more comfortably in daily life is also an important issue. In the paper by Lin *et al.* [37], a novel dry foam electrode was designed and applied to the wearable ECG acquisition device. These

novel dry foam electrodes without conduction gels can provide good conductivity to acquire ECG signals effectively and can adapt to irregular skin surface to maintain low skin–electrode impedance and reduce motion artifacts under movement. It provides a good prototype for ECG telemedicine applications.

We hope that this special issue will serve our *IEEE Systems Journal* readers an avenue to gain a new perspective on systems research in the service sector. We would specially like to thank the Editor-in-Chief, Professor Vincenzo Piuri, for his encouragement and guidance throughout this endeavor. We are also deeply grateful to the many individual reviewers who worked with us so diligently. Without their time, effort, and support, this issue would never have come to be.

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