Proceedings of the ASME Congress 2019 International Mechanical Engineering Congress and Exposition
IMECE 2019
November 8-14, 2019, Salt Lake City, Utah, USA

IMECE2019-11393

COMPUTATIONAL MODEL FOR KNOWLEDGE TRANSFER SKILLS IN INDUSTRY 4.0 IN AN ENHANCED AND EFFECTIVE WAY

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ABSTRACT

The current swift pace of development is a reality that is crossing many domains in society demanding specific measures to cope with such scale of development. In the new paradigm of Industry 4.0, new competences and professional skills are needed in the most diverse quadrants of society. The importance of adequately adapt the societal systems and to promote the adequate skills is worth as much as the value we give to present and future generations. Among demanding challenges arising from this changing reality, the transfer of knowledge from academia to industry is probably the most demanding. This reality is present across diverse countries and continents and for that, pilot deployments and lessons learned should be documented and shared to promote better and effective skill development. In this context, the SHYFTE project is establishing a computational model for knowledge transfer skills in industry 4.0.

1. INTRODUCTION

The majority of Asian countries face rapid radical challenges related to skills development, in the need for becoming compliant with the requirements in an Industry 4.0 ecosystem. According to the World Economic Forum's report, global competitiveness key areas include innovation, technological readiness, infrastructure, institutions, as well as higher education and training. Manufacturing needs to firmly grasp the personnel training, to promote and enhance the innovative skill sets. Specifically, there is an identified gap between current learning programs, in High Education Institutions (HEI), and the skills required by companies reaching the new production paradigms associated to Industry 4.0. The "Skills 4.0 Center of Excellence" network, will develop and establish opportunities facilitating and supporting knowledge transfer between universities and the industrial environments filling that gap. The goal of the present work is to develop a computational model that supports knowledge transfer between academia and industry, and vice-versa, to be applied in those centers. That system aims the support for High Education Institution curriculums, in-line with the industry's skills requirements, and the tuition of a new workers' generation. The addressed skills are recognized as needed by the industry, with a shortage in trained students and a need for the companies to advance and meet Industrial requirements for the ongoing industrial revolution. The operationalisation of such endeavour will be accomplished within 5 days training involving, at least, 60 trainers/teachers and 300 students. In that context, it will focus on the implementation of 4 pilots in Asian countries; China, Malaysia and Thailand. Each pilot will be specialised in one area of expertise relevant for Industry 4.0, specifically, a pilot on Industrial Engineering and Management in Thailand, in China a pilot in Software Engineering & Big Data analytics and another in Wireless Networks Analytics and finally one for Artificial Intelligence in Malaysia. The operational execution of such network is replicable and scalable as the objectives are met and proven its value for the students, the industry and the society in general. In the next section, information systems are presented and summarized.

2. INFORMATION SYSTEMS IN LEARNIG CONTEXT

Information systems (IS) has a tremendous impact in nowadays society in diverse aspects. Those systems can be elicited from main views, such as; technology, social, socio-technological or process [1]:

- Technology view – the systems that include computer hardware and software, manual procedures, models for analysis, planning, control and decision making; and database. However, the central emphasis will be on information technology (IT).
- Social view – the IS it is seen as a social system within information technology.
- Socio-technical view – is examined both from the social and technological perspectives of IS and its intrinsic interactions.
- Process view – IS is viewed as a system which execute processes and its activities are seen with focus on processing information (capturing, transmitting, storing, retrieving, manipulating, and displaying information).

2.1 Learning Platforms

Platforms for learning purposes can be used both for managing the contents to be administered and can be used to deploy the courses either only or locally available. The massive open online courses (MOOC) are a reality adopted by many conventional education institutions to reach a broader audience. But prior to establishing the infrastructure to deploy such courses it is defined the architecture that serves as base to the deployment of a proposed syllabus.

2.2 Service-Oriented Architectures

Service-Oriented Architectures (SOA), is a conceptualization supporting the development of web applications by using web services. Its fundamental concept architecture is represented in Figure 1 [2]. In essence, the services provider is responsible for the design and services implementation, specifying the interface to those services. Then publish the services information in a registry. Those services will be available so that service requesters, when requiring to use a service, discover that service specification and find the specific service provider. Consequently, they will have the possibility to bind their application to such services.

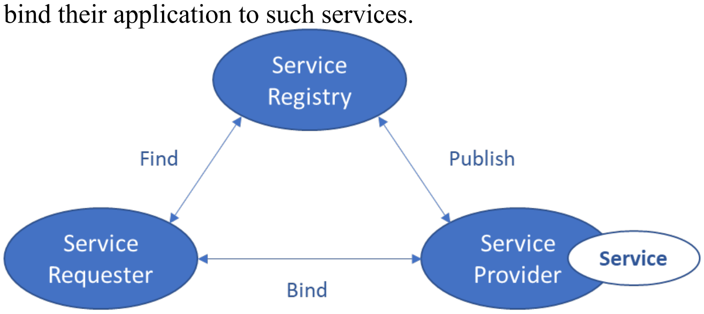

Figure 1 - Service Oriented Architecture

There are a number of key service standards that are created to support web services groups. Those service standards categories are generically listed next in Figure 2.

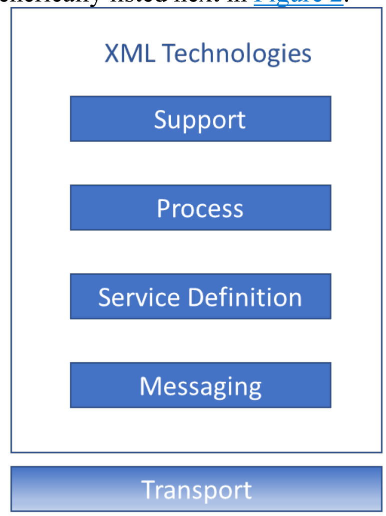

Figure 2 - Web Service Standards [2], all based on XML technologies, organized in categories, specifically: support, process, service definition, and messaging.

The web service protocols widely cover the aspects of SOA. The key standards for web SOA are all based on Extensible Markup Language (XML).

Concerning process of developing services, WS-BPEL is a standard for workflow language to define process programs with different services.

Principal SOA standards are supported by more specialized supported standards, for instance WS-Reliable Security that support web service security concerning security policies and digital signatures; and WS-Transations that defines the coordination aspect of transactions across distributed systems.

WSDL – Web Service Definition Language - is a standard to define service interfaces (i.e. service operations, and service bindings).

Regarding messaging exchange, i.e. a mechanism for action coordination in distributed systems, SOAP is a standard for message interchange allowing the communication between services.

Communication in SOA services is performed through messages exchanging (in XML), which are distributed using standard Internet transport protocols such as HTTP and TCP/IP.

SOA have been widely used for learning platforms, due to its characteristics of adaptability to technological changes and evolutions. To mention some of the key references in this area, Seridi et al. [3] proposed a SOA-based architecture in which 4 types of webservices are identified:

a) course web service – allows the access to remote courses;

b) cognitive level Web service – through this service it is possible to assign a cognitive level to each learner;

c) Collaboration Web service – it allows the development of work in collaboration among a group of learners;

d) Tutoring web service – supports and orients learners. Fajar et al. [4] proposed a detailed system architecture based on SOA, with the aim to interconnect higher education in Indonesia. In this case several stakeholders are considered: students, lecturers/instructors, universities, financial institutions, fund institutions, and employers/industries. The architecture includes six layers, specifically: data layer, resources layer, application layer, business layer, presentation layer, and governance layer.

2.3 Federated Information Systems

According to Susanne et al. [5], by definition, Federated Information Systems (FIS) "consists of a set of distinct and autonomous information system components, the participants of this federation. Participants in first place operate independently but have possibly given up some autonomy in order to participate in the federation". They are designed as an integrating layer over other applications and databases.

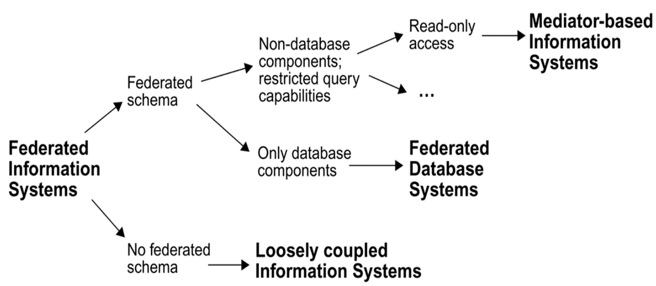

Figure 3 - Classification of Federated Information Systems [5]

A categorization criteria as presented in Figure 3 [5], considers:

- Kinds of Components – refers to structured, semi-structured or unstructured components. Structured sources have a pre-defined schema. In semi-structured data source each data item needs a semantic definition; unstructured data sources doesn't have structure.
- Tight vs. Loose Federation – Tight federation offers a unified schema as access interface to the federation. While, Loose federations does not offer a uniform schema, but offer a uniform query language.
- Data Model of the FIS – is based on a canonical data model or common data model.
- Kinds of semantic integration – at data level, the semantic integration can assume the type of: collection, fusion, abstraction, supplementation.
- Transparency –It gives the perception that a user is interacting with a central and local heterogeneous consistent information system. Can occur at difference levels (e.g. location transparency, schema transparency, language transparency)
- Query Paradigm – classified in "structured queries" or "information retrieval".
- Bottom-up vs. Top-Down – the bottom-up approach is build according to a global information need. In the top-down approach the initial requirement is to have an integrated access to specific data sources.
- Virtual vs. materialized integration – In virtual integration architectures ate temporally materialized. In materialized integration the materialization can be partial or complete on the federation level.

FIS can also be classified into [5]: a) mediator-based information systems; b) federated database systems; c) loosely coupled information systems.

The current work proposes a platform based on both SOA and Federated Information Systems. SOA was chosen due to its characteristics of adaptability, which is useful for the envisioned continuous technological evolutions in educational education context. Federated Information Systems choice is based on interoperability, distribution, modularity, and extensibility, which is adequate to the planned architecture needed that will have a network of connected education centres (Figure 5).

3. SHYFTE Project

SHYFTE – Building Skills 4.0 through university and enterprise collaboration is an Erasmus+ project, that allows Skills 4.0 Labs. Asian countries of China, Malaysia, and Thailand, will host the *Skills 4.0 Center of Excellence Network* that will improve required skills for Industry 4.0 in four domains of specialization, specifically: a) industrial engineering and management; b) software engineering and big data analytics; c) wireless and networks analytics; and d) artificial intelligence.

3.2 SHYFTE Knowledge Transfer Conceptual Model

The conceptual model of SHYFTE project (*Figure 4*), that is the basis for the Skills 4.0 Center of Excellence Network system functioning, is composed by several components, next described.

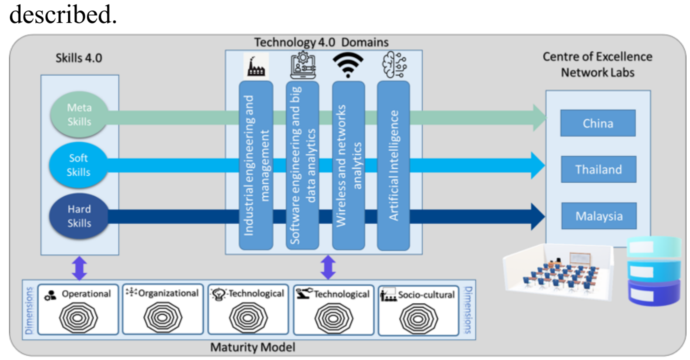

Figure 4 - SHYFTE Knowledge Transfer Conceptual Model

Skills 4.0 Center of Excellence Network Labs – refers to the four pilots to implement in Asia: Pilot in Thailand; Pilot 2 in China; Pilot 3 both in Malaysia and China; and Pilot 4 in Malaysia.

Technological 4.0 Domains – The *Center of Excellence Network* Labs will specialize pilots in four Industry 4.0 domains:

a) industrial engineering and management (Pilot 1); b) software engineering and big data analytics (Pilot 2); c) Wireless and networks analytics (Pilot 3); and d) artificial intelligence (Pilot 4).

Skills 4.0 – in the scope of the SHYFTE project, the four previously mentioned technological domains are analysed from the skills point of view. That analysis considers the categorization of skills: a) meta skills; b) soft skills; c) hard skills.

Maturity Model – this model will both allow to characterize the maturity level of the enterprise, and with that information propose the skills and domains required for each concrete case.

From the technological perspective, the main goal is to have advanced services supporting the *Skills 4.0 Center of Excellence,* available in a virtual learning environment with learning materials developed to improve students' skills.

The SHYFTE platform supporting the scenario will be tested during 5 days of training, 60 trainers/teachers, 300 students, in 4 pilots in Asia (China, Malaysia, Thailand).

Considering what was previously said, it would be desirable that the *Skills 4.0 Centre of Excellence network would be easily replicable and scalable*. However, maintaining the identify of each institution.

With such presented deployment, it is rightful to ask, if not for SHYFTE, which other information system could better implement this behavior?

3.3 Architecture

SOA is a reliable basis integrable architecture for a platform supporting the *Skills 4.0 Centers of Excellence Network*, by the following reasons:

1. modularity – services are easy to replace, since are dynamically coupled;
2. interoperability – refers to the use of standard protocols in services communication and specification;
3. Extensibility – previously mentioned characteristics (1 and 2), allows the system to be easily extended.
4. Cost reduction – regarding the possibility of reuse existing services during the development process;
5. Distribution – services can be developed in different languages and distributed in different servers.

Another emergent aspect to consider in the platform architecture supporting the *Skills 4.0 Center of Excellence Network* refers to the existence of different not centralized organizations, i.e. the Asian Universities supporting pilots. Considering that there are always differences of modus operandi for one place to another, it is important to consider the local differences, and simultaneously protect the integrity of the *Skills 4.0 Center of Excellence Network* as a whole, processing the same things in the same way maintaining consistency.

Analyzing the case under study in this perspective, it will be required to implement a federation of several domains with separate spheres of influence, that can find how to interoperate.

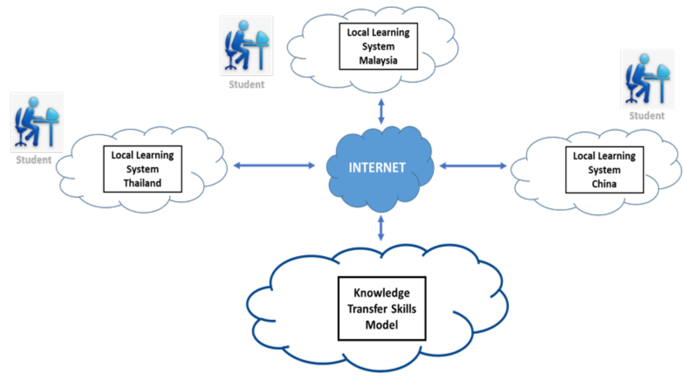

Figure 5 - SHYFTE Architecture Diagram – Global and Country Layers

Thus, the proposed solution displayed in *Figure 5*, includes three stratified federation levels, specifically:

1. Global level – at knowledge Transfer Skills Model level.
2. Country level – Concerning China, Malaysia and Thailand.
3. University level – Allows to respect specifications at university level for each country.

The centers of excellence, concerning its digital learning environment, is being designed to integrate tools for learning, and the "Knowledge Transfer Skill Model", a curriculum recommendation system based on skills required for Industry 4.0 in four SHYFTE domains: Industrial engineering and management; software engineering and big data analytics; wireless and networks analytics; and artificial intelligence. The system also provides general services, such as authentication, and a storage service.

For this service-oriented system, it is envisioned three types of system [6]:

- Utility services – basic application-independent functionalities;
- Application services - include specific educational contents;
- Configuration services – adapt to the environment in order to define how services are shared among users.

SHYFTE Knowledge Transfer Skills service-based architecture includes services of three aforementioned types. In that context, configuration services refer to group and application management. Application services include SHYFTE educational contents for each of the four domains, such as simulation, video storage, virtual learning environment and resource storage. Finally, utility services, are basic services, for instance system authentication, user and application storage, interfacing and search.

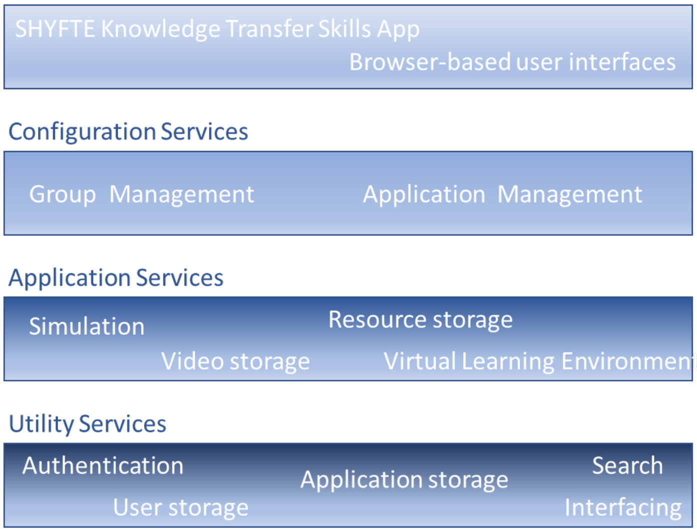

Figure 6 - SHYFTE Knowledge Transfer Skills service-based architecture.

The system will be able, for instance to recommend an online training program based on student maturity skill for the SHYFTE domains: industrial engineering and management; software engineering; big data analytics; wireless and network analytics; and artificial intelligence.

Additionally, it is planned the system to customize online training recommendations for a specific task or job in the aforementioned domains. In the software development process is being defined specific user stories, as for instance in relation to the mentioned function: "As a student I want to have skills to perform a task in Artificial Intelligence domain of Industry 4.0". At this moment the SHYFTE Knowledge Transfer Skills ontology is under preparation, in order to support the system answering such kind of questions. Thus, all the knowledge to define the various domains and formalize all the training characteristics as the various skills has been modelled. In the near future the SHYFTE Knowledge Transfer Skills services will be available, without disruption in Center of Excellence Network Labs located at China, Thailand, and Malaysia (Figure 4).

4. CONCLUSIONS AND FUTURE WORK

The present work is addressed in the context of *SHYFTE Skills 4.0 Centre of Excellence Network*, promoting knowledge transfer at pilots in Asian Countries. Specifically, it aims to deploy and demonstrate a skills transfer infrastructure for Industry 4.0. The proposed approach for the *Computational Model for Knowledge Transfer Skills in Industry 4.0* is based on the Service Oriented Architecture (SOA). In the proposed case, SOA is implemented with a Federation based approach assumed as the most adequate solution to support the *Skills 4.0 Centers of Excellence Network* services. Main reasons supporting that choice, as hereby reported, it allows a combination of interesting characteristics, specifically: the contents can be reused by all partners, allows to have local contents, allows different federated layers. Future work will include the development of the Knowledge Transfer Skills Model (Figure 5), which will allow to the deliver the appropriated skills concerning the maturity of the enterprise in a virtual way. Additionally, an economic evaluation of the impact of a center as the proposed will be accomplished in the near future.

ACKNOWLEDGEMENTS

The SHYFTE project referred by "598649-EPP-1-2018-1-FR-EPPKA2-CBHE-JP" has been funded with support from the European Commission. This publication reflects the views only of the authors, and the Commission cannot be held responsible or any use which may be made of the information contained therein.

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