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A conceptual model for the acceptance of collaborative robots in industry 5.0

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Abstract

This study provides a holistic view of the acceptance of collaborative robots (cobots) in the manufacturing context by adopting the socio-technical perspective to the Industry 5.0 era. Grounding on the Unified Theory of Acceptance and Use of Technology (UTAUT) and Socio-Technical Systems theory (STS), this study proposes a conceptual model to better understanding critical factors that influence the acceptance of cobots and how these factors can drive perceived work performance improvement in the organizational level. This study was conducted by catching the critical issue, reviewing the literature on the subject of this study, identifying previous research gaps, and subsequently developing constructs of the model. As a result, this study offers valuable contributions to robotics and manufacturing literature and further suggests empirical research to generally examine and validate the conceptual model.

Keywords: Cobots; industry 5.0; socio-technical; acceptance; UTAUT; STS; perceived work performance improvement

1. Introduction

The Sustainable Development Goals (SDGs) aim to promote sustainable economic growth by achieving productive employment through technological innovation. Concerning these targets, most emerging and developing countries place advanced technological manufacturing as an essential engine of their economic growth to deal with the new industrial revolutionary wave. While the Fourth Industrial Revolution (Industry 4.0) has brought rapid technology advancements to achieve high performance, the new industrial stage—termed Industry 5.0—will bring synergistic relationships between technological and social systems to deliver personalized mass customization of products and services [1]. Industry 5.0 demands a socio-technical evolution of the human role in manufacturing systems, in which

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all operational activities of the value chain will be performed with smart approaches [2][3] and floored in advanced information and communication technologies [4].

The use of collaborative robots (hereinafter referred to as cobots) is one such endeavor to move towards smarter manufacturing systems in facing Industry 5.0. Manufacturing work can be improved to reduce low added value tasks of workers by using cobots and taking advantage of workers' potential for more advanced tasks in which robots are limited due to the flexibility of the tasks [1][5]. The ability of cobots to seamlessly interact with humans in a sophisticated workspace becomes a valuable advantage that potentially expands the application of cobots in the manufacturing industry. Considering cobots are expected to synergistically work with human workers, a critical issue that arises is the acceptance of cobots at the workplace. Unfortunately, to the best of our knowledge, no existing study provides an organizational-focused concept regarding the acceptance of cobots in the manufacturing works environment. A recent study by Simoes et al. [6] has initiated to identify the factors that influence managers' intention to adopt cobots in manufacturing companies but did not discuss further in the actual usage stage. Besides, only a few studies have examined the expectations and success factors in implementing cobots within the areas of manufacturing systems [7][8][9].

In the smart working environment with cobots are designed to work alongside human workers, it is crucial to have a great understanding of how they can interact so that the workflow runs as smoothly as possible [10]. It is also necessary to break the generally known paradigm of strictly separating the workplace into a human and a robotic area by creating a shared workspace [11]. The design of a shared workspace will influence the factory's work systems and thus make way of allocating work between human workers and cobots a vital issue. However, to the best of our knowledge, no prior study proposes an integrative conceptual model by emphasizing the close interplay between human workers and cobots in the manufacturing works environment. Moreover, most previous studies focused predominantly on technical challenges of cobots implementation or investigate interactions with social or humanoid robots in the service context [9].

This study aims to delineate a holistic view of the synergistic relationship between human workers and cobots by adopting the socio-technical perspective to the Industry 5.0 environment. Drawing on the Unified Theory of Acceptance and Use of Technology (UTAUT) and Socio-Technical Systems theory (STS), this study proposes a conceptual model from an organizational-focused concept and presents critical factors that influence the behavioral intention and actual use of cobots in the manufacturing works environment. This study suggests a further empirical study to examine and validate the proposed conceptual model as well as helps in focusing research efforts to support the broader implementation of cobots in the manufacturing industry.

1. Literature Review

2.1 Industry 5.0 and Socio-technical Perspective

The concept of Industry 5.0 can be characterized by human intelligence working side by side in a workspace with cognitive computing to produce more value-added products [1]. As a new evolutionary stage where the human and machine work together in perfect symbiosis with one another, Industry 5.0 will significantly restructure human tasks and impact work systems in the realm of manufacturing [2]. Human workers will be upskilled to cognitive labor to complete value-added tasks and focus on supervising and decision-making roles. On the other hand, an autonomous machine will perform specified tasks to assist human workers in a shared workspace [12][2]. While humans focus on tasks utilizing brainpower and creativity, an autonomous machine (e.g., cobots) is needed to work alongside humans as collaborators to increase process efficiency and productivity [13].

Considering the primary concern in Industry 5.0 is about a synergy between humans and autonomous machines, the desire for mass-personalized products and services will emphasize social and technical relationships in the workplace [14]. By putting a crucial role of human workers back to factory floors, Industry 5.0 will bring challenges to the welfare of human workers interacting with the design of smart working systems in an organization. Arguably, these challenges can only be countered effectively if socio-technical perspectives are applied. Bednar and Welch [1] also argued that any innovation effort in pursuance of developing a smart working environment must be considered from a socio-technical perspective. They also suggested that the socio-technical systems approach is deemed imperative to supporting the use of smart technologies in organizations. Thus, this study rises socio-technical roles considering as critical factors for cobots' acceptance by manufacturing companies in the Industry 5.0 era.

2.2 The Introduction of Cobots in the Manufacturing Industry

In recent years, the cobots application has snowballed. The market size estimation of cobots was $649 million in 2019, and it would be growing at the rate of 45% duration 2019 and 2025 [15]. Manufacturing companies introduced cobots in production environments to increase productivity, usability, and flexibility [12]. Cobots can minimize the risk or error in operations compared to the manual workforce, and in the production process, special personnel is needed for supervision in each step of production [12]. Cobots are characterized by robots that work simultaneously with human workers in a job in the same room but do different things [6]. In this sense, cobots are designed to assist humans with various tasks in a shared workspace. Hence, the use of cobots allows human workers to focus more on developing innovative solution and decision-making roles [12]. From a technical perspective, cobots have good values compared to traditional industrial robots regarding user-friendliness and flexibility. Cobots are flexible to handle complete repetitive and boring jobs and ergonomically challenging tasks [12]. They have integrated sensors to reliably detect intentional or unintentional contact with their environment [9]. Thus, aspects of safety, proper function, and ease of use are essential factors that significantly influence the natural interactions of cobots with human workers [8].

The important use of cobots in the manufacturing industry has been noted in several previous studies. For instance, Calitz et al. [12] investigated the current use and future implementation of cobots worldwide and their specific impact on the African workforce. Their findings indicated that the mobility and flexibility provided by cobot solutions would create a sustainable work environment of the future. Simoes et al. [6] identified 39 factors influencing the intention to adopt cobots based on a conceptual framework that integrates Diffusion of Innovation theory, Technology-organization-environment theory, and Institutional theory. However, these studies have been done qualitatively. On the other hand, few other studies have discussed expectations and success factors in adopting cobots from the standpoint of industry and academia [7][8]. The findings from Aaltonen and Salmi [7] emphasized that the most significant development needs of cobots were about new ways of allocating work between human workers and cobots. In addition, a recent study from Bi et al. [15] has summarized some representative developments of cobots in different applications. Based on their works, most prior studies focused predominantly on the technical challenges of cobots application in manufacturing processes.

In the collaborative work environment, the manufacturing companies implementing cobots might face different challenges related to the actual use of cobots. The actual use of cobots will eventually determine the success of human–cobots collaboration in a smart working environment [12]. The acceptance of cobots by human workers, when the cobots are first introduced, can be achieved only when they are involved from the early implementation process (e.g., defining the work conditions). Subsequently, the use of cobots can offer significant potential for improving the design of work systems and how work is organized as well [6]. The manufacturing companies should consider task requirements and design considerations, including safety and trust assurance, ergonomics, and the flexibility to deal with the changes [15].

2. Theoretical Background and Conceptual Model

3.1 The Unified Theory of Acceptance and Use of Technology (UTAUT) and Socio-Technical Systems (STS)

Venkatesh et al. [16] introduced UTAUT as a comprehensive synthesis of several prior technology acceptance models. In the organizational context, UTAUT has sifted the critical factors related to predicting behavioral intention to use a technology and technology use primarily [17]. UTAUT defined that acceptance covers two steps, i.e., the behavioral intention and the usage behavior. It is critical to understand the different dynamics of intention and actual use to study the acceptance of new technology or systems. Hence, this study utilizes this theory to explore the acceptance of cobots in the manufacturing works environment. By using UTAUT, this study exhibits different implications for the intention to use cobots when it is first introduced, as well as its continuing actual use. Thus, the intention to use cobots is viewed here as a company's desire to use cobots in daily manufacturing works. Given that manufacturing works were abounding with the interaction of cobots and human workers at the workplace, the actual use of cobots reflects the extent to which a company continues to use cobots to improve work performance.

Though UTAUT has been used by several prior studies on human-robot interaction [18][19][20], unfortunately, these studies focused on health care and education to study the acceptance of social robots. It indicates a valuable contribution to the manufacturing and robotics literature by utilizing UTAUT in predicting the critical factors that influence the behavioral intention of using cobots. However, UTAUT lacks an explanation of the synergistics relationship between human workers and cobots in the manufacturing works environment. Therefore, this study proposes that the UTAUT should be amalgamated with other theory which emphasizes the close interplay between human workers and cobots in the actual usage behavior phase.

The actual use of cobots cannot be viewed as an entirely technological concern. It demands socio-technical roles in which the interaction of people and technology is carefully considered, especially when focusing on the level of organizations, systems, and works. A wide range of socio-technical approaches has been developed and applied as an organizational tool for evaluating the design of work systems and modifying the workplace environment, specifically in manufacturing and production works setting [21][22]. In the information systems (IS) literature, STS has provided principles for designing and implementing new technology or systems with a balance between social and technical factors [23][21].

According to Patnayakuni and Ruppel [22], based on STS theory, an organizational work system is viewed as an open system interacting with its environment that consists of two interdependent subsystems (i.e., the social and the technical). Bringing together both subsystems in work environments is more likely to obtain favorable outcomes for an organization. On the same hand, work design has been considered an important factor to be able to enhance an organization's outcomes (e.g., the increased productivity) as well as the improved quality of work life. In this instance, an organization must recognize the need to integrate social and technical systems together in designing work systems to achieve work performance improvement. In the context of manufacturing, the actual use of cobots will depend on a company's ability to design the practice of manufacturing works that incorporates the technical subsystem with the social subsystem. As a company designs its work system based on STS, the company will not experience significant obstacles in the use of cobots which means the level of actual use will increase and further resulting in perceived work performance improvement.

This study views STS could emphasize the close interplay between human workers and cobots in the actual usage behavior phase. Thus, this study amalgamates UTAUT and STS to provide a theoretical basis for exploring the acceptance of cobots in the manufacturing company. It indicates a valuable contribution to the manufacturing and robotics literature by proposing an integrative conceptual model to provide a holistic view of the usage intention and actual usage of cobots in the manufacturing company. The proposed conceptual model is shown in Fig. 1.

3.1.1 Four Dimensions of UTAUT on Intention to Use Cobots

This study utilizes UTAUT in predicting the critical factors that influence the behavioral intention of using cobots at the organization level. UTAUT suggests four key dimensions: performance expectancy, effort expectancy, social influence, and facilitating conditions, as direct determinants of intention and usage behavior. In this study, performance expectancy is defined as the extent to which using cobots will provide benefits to company in performing certain works. Effort expectancy is defined as the extent to which a company perception of ease associated with the use of cobots. Social influence is defined as the extent to which a company perceives that important others believe they should use cobots. Lastly, facilitating conditions are defined as the extent to which a company believes that an organizational and technical infrastructure exists to support the use of cobots. The research proposition assumes that these dimensions influence a company's desire to use cobots.

3.1.2 Three Dimension of STS on Actual Use of Cobots

This study adopts STS to explore the factors that affect the actual use of cobots by considering an integrated approach of the social and technical subsystems in the design of organizational work systems. In this study, the social subsystem is viewed here as a company's capacity to change and adapt to cobots' usage, which is specific associated with the diffusion of control and the extent of informal communication. The technical subsystem is characterized by cobots' implementation environment and the integration level of cobots at the workplace. At last, work design in a company can be characterized by the type of organization, use of teams, and tasks specialization. The research proposition assumes that these dimensions influence the level of actual use of cobots.

3.2 Perceived Work Performance Improvement

The concept of perceived work performance improvement was developed as a subjective measurement of working performance [24]. Yueh et al. [24] revealed that usage behavior is the sufficient condition of perceived improvement of work performance. Several previous studies [25][26] have also exhibited that technology usage behavior has an impact on perceived work performance improvement. For instance, Bryant and Allen [25] demonstrate the relationship between technology use and work performance by surveying 200 employees in startup organizations. Their results displayed that the employees finish work tasks more efficiently using mobile technology. Thus, this study proposes perceived work performance improvement as one of benefits derived from actual use of cobots. In this study, perceived work performance improvement is referred to how useful cobots are to a company in helping to complete the company's work. Therefore, the research proposition assumes that behavioral intention to use cobots will affect the actual use of cobots which result in enhancing perceived work performance improvement.

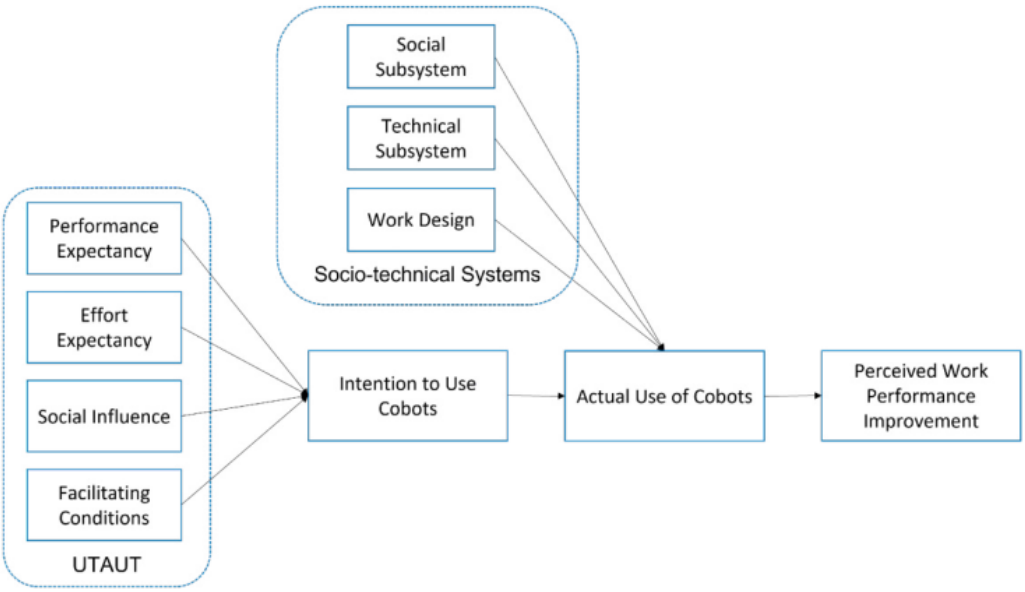

Fig. 1. Conceptual model for the acceptance of collaborative robots in industry 5.0

3. Conclusion and Future Works

In the new era where the development of technology is very fast-changing, manufacturing companies are required to continuously adapt their production strategy with the implementation of advanced technology to meet the market's needs. Manufacturing companies need to prepare to move towards Industry 5.0, which is very open to them. Industry 5.0 will dramatically alter manufacturing systems towards greater productivity and efficiency. This requisites manufacturing companies to adopt and use autonomous workforces to support the smooth running of their manufacturing processes. By keeping the value of human workers on the production floor, human workers are expected to keep up with technological advances by developing innovations and synergizing in the collaborative environment. Thus, using cobots in manufacturing systems eventually brings many advantages as these autonomous workforces enable more productive and efficient production systems by assisting human workers with specific tasks.

To deal with the aforementioned challenges, this study brings the socio-technical perspective to Industry 5.0 by offering a holistic view of the synergistic relationship between human workers and cobots in the manufacturing work environment. In sum, this study proposes an integrative conceptual model that emphasizes the close interplay between human workers and cobots. This study contributes to the literature by providing a concept of the acceptance of cobots from an organizational-focused viewpoint. This study extends previous literature by looking forward to the long-term effect of the behavioral intention on the actual use of cobots and further on perceived work performance improvement in the organizational context. In the future, this study can be continued by developing the measurement items of all constructs mentioned in this paper and subsequently collecting the data from the appropriate population of manufacturing companies. Then, an empirical study can be conducted to examine and validate the conceptual model resulting from this research. These future works will help in realizing research efforts to support the broader implementation of cobots in the manufacturing industry.

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