The Digitalization Principles from a User-Centered Design Perspective – A Conceptual Framework for Smart Product Development

Carolina Sallati, Klaus Schützer

The industry relies on interdisciplinarity to promote advancements. The diverse engineering domains, information technologies, management and social sciences are combined in the industrial environment and oriented o society's ever-changing demands. In parallel, the demographic shifts caused by population aging present room for innovation on many fronts, such as in health, technology, industry, products, and services, and in the same way in product development processes. In an attempt to tackle such issues, this article discusses how the addressing of the elderly population demands, particularly the demand for smart products, might be supported by the principles of production digitalization. In doing so, it proposes a conceptual framework for the development of smart products for the elderly, sustained by three core pillars: specific product lifecycle stages, Industrie 4.0 requirements for smart product development; and Industrie 4.0 enabling technologies which are integrated by the User-Centered Design philosophy. Their combination into a framework aims at addressing two main points: assist in the translation of elderly real consumers' expectations and demands into more adequate, appealing products and in creating a transition path for companies who wish to incorporate the principles and technologies of production digitalization in their value chain. Furthermore, the article discusses how this proposal could be validated in the real industrial environment.

Keywords: User-Centered Design, Smart Product Development, Digitalization Principles, Silver Market.

Introduction

Social and cultural contexts influence scientific progress, innovation, and technology development. As humanity evolves, it creates new tools and explores resources in different ways to meet new needs and demands. Over the past few years, discussions revolved around the changes caused by the 4th Industrial Revolution, also dubbed *Industrie 4.0* (Kagermann, Walhster, & Helbig, 2013; Platform Industrie 4.0, 2016). The focus of such discussions has been directed to questions regarding how the production of goods should be conducted in face of the upcoming digitalization possibilities and principles, how to address different stakeholders' requirements, to cope with the increasing demand for customized products, and to support new business models (Rauch, Dallasega, P, & Matt, 2016; Santos, Loures, Piechnicki, & Canciglieri, 2017). Successfully coping with such changes requires more than industrial resources; it takes a broadening of perspective and the inclusion of important factors such as population aging at a fast rate (United Nations, 2017). This global phenomenon is key to industry and, therefore, to the *Industrie 4.0* paradigm, on two fronts. Primarily the workforce is aging, pressing for solutions concerning workstations adaption, continuous learning strategies and carriers, knowledge transfer, and intergenerational work (Kagermann, Walhster, & Helbig, 2013; United Nations, 2017). Secondly, new market opportunities are rising. As people experience aging differently due to environmental, social, and physiological conditions, once considered established desires might change and yet new ones might arise (Kohlbacher, Herstatt, & Helbig, 2011). Such a wide range of aging scenarios creates opportunities for the development of solutions in the areas of health, technology, services, and products in what has been called the Silver Market. However, as great an opportunity the Silver Market poses in terms of innovation, as great the challenges it presents. Although the different needs and desires which translate themselves into highly customized features for services and products may find support in the digitalization principles for their realization, it is unwise to address them superficially. Designing solutions for the elderly, or the Silver Market, stretches further from the identification of needs derived from social conditions or health limitations. It requires considering what Maslow called "higher needs" (Maslow, 2019); that is, to identify aspects related directly to one's perception of self and their core beliefs. Put differently, the challenge in designing for the Silver Market lies in translating high subjectivism into feasible features. Therefore, the line of action to be taken starts at the development process of products, services and their evolved "in-betweeners": the product-service systems (PSS). With such background, the present work discusses how *Industrie 4.0* and the production digitalization principles might support the development of more attractive PSS, or smart products as they shall here be called, for the Silver Market. In doing so, a conceptual framework for the development of smart products for the Silver Market based on a user-centered design philosophy is proposed.

Research Approach

The present study was conducted following Design Science Research guidelines added of bibliographical and documental analysis. An extensive literature review identified a total of 21 *Industrie 4.0* requirements for the development process of smart products and 12 associated technologies, here called enabling technologies. The review also identified 23 sample cases of successful smart product development for the Silver Market from the Active and Assisted Living (AAL) Programme (AAL Programme, 2015; AAL Programme, 2016). The findings were refined according to the following criteria: the requirements and technologies incorporated into the framework had to be associated with three specific product lifecycle stages – product planning, product design, and usage. The reasons for such a decision are denoted in the next section. Thus, only 13 requirements and nine enabling technologies are addressed in the framework. Concerning the sample cases, only four were analyzed in-depth and used as comparison parameter for the framework as they met the following criteria: be classified as product-oriented PSS (Beuren, Pereira, & Fagundes , 2016); present official product development documents, scientific publications, or public presentations material; be classified as development and not improvement projects; not involve clinical trials. The cases analysis assessed aspects related to user and data integration, particularly how users were integrated into the product development process; what tools and methods were used for their integration; how usage data was utilized in the process; whether and how the PSS development processes related to *Industrie 4.0* digitalization principles. The analysis results were compared to the found requirements and enabling technologies, thus originating the framework.

The *Industrie 4.0* Environment and the Digitalization Principles

The *Industrie 4.0* initiative has been a synonym for the 4th Industrial Revolution. Accordingly, the initiative proposes changes in the industrial environment stemming from the advancements of information and communication technologies (ICTs) in the production processes which, in consequence, affect comprehensively the entire value chain (Kagermann, Walhster, & Helbig, 2013; Platform Industrie 4.0, 2016; Schmidt, et al., 2015). However, technologies themselves are not what represents the initiative's disruptive character. Rather, how their combination and association to new market trends, like product customization, servitization, and the arising of new consumer publics, provides the connection between the physical and digital worlds, ultimately shifting how businesses are conducted (Rauch, Dallasega, P, & Matt, 2016; Schmidt, et al., 2015). Such changes in the industrial environment can be understood as the digitalization principles. Adhering to them does not require only integrating new technologies. It requires interdisciplinarity to combine expertise across different knowledge domains. Thus, one actor remains in the process central: human effort. acatech's report in 2016 (Platform Industrie 4.0, 2016) state people must be at the center of the 4th Industrial Revolution not merely as technology providers and managers but also as its prime goal.

Therefore, human-centered processes also pose as a digitalization principle. However, such discussions are still scarce, particularly when related to product development and how it should fit into the *Industrie 4.0* environment. Few examples can be found that apply the digitalization principles to the product development process (Rauch, Dallasega, P, & Matt, 2016; Santos, Loures, Piechnicki, & Canciglieri, 2017; Schmidt, et al., 2015; Nunes, Pereira, & Alves, 2017). One of them proposes a gradual transition from traditional products to their *Industrie 4.0* counterpart, the *Industrie 4.0* Toolbox for Products (Anderl & Fleischer, 2016), also related to the Reference Architectural Model *Industrie 4.0* – RAMI 4.0 [see (Platform Industrie 4.0, 2016; Wang, Towara, & Anderl, 2017)], which displays the product development process as the value chain guide. However, even such models fail at introducing specific guidelines for adapting the product development process to the *Industrie 4.0* environment. Although they state what is necessary for a "Product 4.0", they do not detail how to implement such requirements in order to comply with the digitalization principles.

Such a background led to the identification of the following digitalization principles: human effort and technology integration; seamless data and information flow through the value chain; product development process as the value chain guide; efficient data usage in the product development process; gradual transition from traditional to connected (4.0) production and products; human-centered processes. Together with the User-Centered Design philosophy, these principles constitute the foundation of the framework discussed ahead.

The Market of Demographic Aging and the User-Centered Design Philosophy

International organizations have documented an accelerated growth of elders in the world population in the last decade (United Nations, 2017; European Communities, 2006; World Bank, 2011). However, reports from the World Health Organization (United Nations, 2017) and the European Commission (European Communities, 2006) stressed the aging process in developed countries occurred gradually, allowing them time to adapt to new demographic and economic realities. The aging process in developing countries, on the other hand, unfolds at an accelerated rate. Comparatively, 2011 projections indicated that by 2025 Brazil would have taken a fifth of the time it took France and the Scandinavian countries to reach 14% of elders in the total population. Such an unsettling scenario presses for assertive measures in several areas but addressing the aging population market, dubbed Silver Market as a homogeneous entity is unwise. The aging processes creates distinct market niches, as people of the same age, that lived in the same social context experience aging differently. As consequence, they develop different needs and expectations regarding consumption habits, as well as different perceptions of self and changing core beliefs over time (Kohlbacher, Herstatt, & Helbig, 2011).

It means developing solutions suitable to this market in innovative ways can not only foster a healthy, active aging lifestyle but also scientific and technological advancements. Following that perspective, the European Union inaugurated in 2008 a systemic Silver Market-oriented development program for ICT-based products and services, the Active and Assisted Living (AAL) Programme, which funded cooperative projects between universities, research centers, and small and mid-sized companies (AAL Programme, 2016). Among the program's success cases are those utilized as comparison models for the framework. The common aspect was the use of the User-Centered Design philosophy.

The User-Centered Design (UCD) can be understood as a design process involving different methods, tools, and activities or as a design philosophy. The latter aims at actively engaging the user in the development process, as means of identifying objective demands and subjective, higher needs through the utilization of its associated methods and tools (Roy, Neumann, & Fels, 2016; Haas, 2019). The UCD philosophy principles and guidelines comprise accessibility needs, diverse capacities, and safety for product usage without restricting design to users' limitations. It also enables the identification of potentially interesting, from a business perspective, needs or demands through the assessment of the customers' core beliefs, perception of self, and lifestyle-related desires and expectations (Kohlbacher, Herstatt, & Helbig, 2011; Planinc & Kampel, 2013; Coughlin, 2017). Thus, the UCD philosophy fosters the development of stimulating products, that encourage users to act autonomously regardless of possible limitations.

In the context of *Industrie 4.0*, the UCD philosophy might assist in a consistent, structured customer integration from an early stage in the product development process. This would be key to assertively identify and categorize customers' needs, expectations, and translate them into feasible, commercial characteristics (Roy, Neumann, & Fels, 2016; Haas, 2019).

The Framework

Core Elements and Main Goals

Having *Industrie 4.0* digitalization principles and the UCD philosophy as background, a conceptual framework for smart product development is presented. The framework basis are four core elements: three product lifecycle stages, here called interest stages; *Industrie 4.0* requirements, divided in three categories compliant with the RAMI 4.0; *Industrie 4.0* enabling technologies; and the User-Centered Design (UCD) philosophy, as demonstrated in Figure 1. The elements are related as follows. Each interest lifecycle stage has specific requirements to attend. To fulfill such requirements, specific enabling technologies are employed in the activities and tasks of each interest stage. Both the requirements and technologies chosen to address them can follow an implementation plan over time, allowing the company to adjust to the *Industrie 4.0* context. By fulfilling the requirements with the aid of the enabling technologies, under the UCD philosophy guidance and employment of UCD tools as necessary, an adequate, appealing smart product emerges at the end of the process, meeting the framework' first goal.

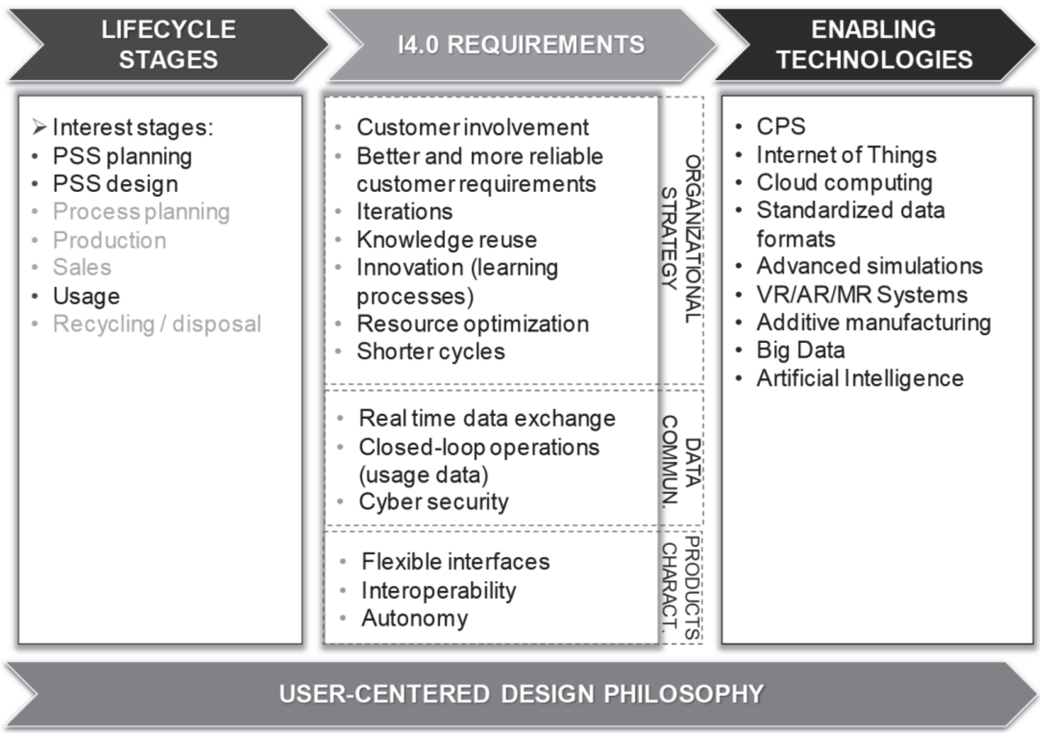

Figure 1: The conceptual framework for development of smart products for the Silver Market compliant with Industrie 4.0 digitalization principles

The framework was conceived as a tool with two primary goals. First, to assist in the development of smart products for the Silver Market that properly fit elder population needs and expectations. The Silver Market comprises specificities potentially considered as restrictions, such as reduced mobility, chronic, progressive health conditions, complex care routines, potentially low tech-literacy (Kohlbacher, Herstatt, & Helbig, 2011). However, such objective needs are not the only the framework aims at addressing. Rather, it seeks to address subjective needs related to one's core beliefs and perception of self. Such needs relate, i.e., to the stigma of requiring care and the autonomy and independence loss that follows; market and family pressure for relying on technology; substitution of personal, human care for technology (Coughlin, 2017). These represent the great challenge in designing for the Silver Market and are precisely the niche at which the framework aims. By including the UCD as a guidance philosophy and glue between the core elements, and by incorporating UCD methodologies as complementary resources to smart product development, the framework envisages to explore users' subjective, higher needs and translate them into feasible product features, that combined with features addressing objective needs might conceive highly attractive, adequate smart products. Secondarily, the framework aims at fostering future exploration of new business models for the Silver Market, stemming from an adaption of the product development process to the *Industrie 4.0* context. For such an adaption path, *Industrie 4.0* requirements and enabling technologies, are considered.

The Interest Lifecycle Stages

As stated earlier, from the total 21 *Industrie 4.0* requirements for smart product development, only the 13 above mentioned are compatible with the scope of this work, which addresses the requirements related to the interest stages, product planning, product design, and usage for the following reasons. Primarily, all three stages have room to expand customer involvement through the integration of new technologies and complementary methods. In the planning and design stages, the most relevant decisions about product characteristics are made; general and specific requirements are gathered through market research and analysis, as well as the range of functionalities, integrated services, and further features are defined, thus resulting in a map of the product. In the product planning stage, the identified market demands and opportunities, therefore, the customers' requirements are analyzed comparatively to the company's goals, resulting in decisions about new products and their expected features, functions, services, and added value. In this stage, such decisions are translated into detailed models or prototypes that will be tested and improved as needed (Pahl & Beitz, 2007; Rozenfeld, 2006). Thus, strategic alignment and customer involvement are key for defining features corresponding to customers' real needs and expectations, especially when addressing higher, more subjective needs (Maslow, 2019). The usage stage presents the possibility of feeding usage data back into the cycle, posing as a source for updates, corrections, and future modularization (Rauch, Dallasega, P, & Matt, 2016; Barth, 2013; Guérineau , Rivest, Bricogne, Durupt, & Eynard, 2018). Besides, processed usage data might render insightful information about new products features, functions, or new products entirely (Schmidt, et al., 2015; Olsson & Bosch, 2013).

Accordingly, the requirements are important for two main reasons: for achieving competitive advantage, once they lead the transition path from traditional to *Industrie 4.0*-compliant development processes when associated to the corresponding enabling technologies, and for providing customer satisfaction, given customer involvement has been demonstrated to assist in acquiring better and more reliable requirements (Kohlbacher, Herstatt, & Helbig, 2011).

The Requirements and their Categories

It is inaccurate to state *Industrie 4.0* displays a static list of requirements for smart product development. However, literature indicates aspects worthy of attention in the product lifecycle (Rauch, Dallasega, P, & Matt, 2016; Nunes, Pereira, & Alves, 2017). Such aspects, and, therefore, the derived requirements, can be divided into three categories following the RAMI 4.0 stratification [see(Platform Industrie 4.0, 2016; Wang, Towara, & Anderl, 2017)]: Organizational Strategy, Data Communication, and Product Characteristics. The requirements within the Organizational Strategy category relate to the strategic decisions that set the course of the company's processes – among which product development – made within the Business layer and Company hierarchical level. They are customer involvement, better and more reliable customer requirements, shorter development cycles (Rauch, Dallasega, P, & Matt, 2016); iterations, resource optimization, innovation through learning processes (Nunes, Pereira, & Alves, 2017); and. knowledge reuse (Barth, 2013).

The second category of requirements, Data Communication, considers interactions between all layers and hierarchical levels within the company (Rauch, Dallasega, P, & Matt, 2016; Wang, Towara, & Anderl, 2017; Nunes, Pereira, & Alves, 2017), ensuring the continuous flow of information about the product lifecycle along the value chain. It comprises the following requirements: closed-loop operations, cybersecurity (Guérineau , Rivest, Bricogne, Durupt, & Eynard, 2018); and real-time data exchange (Rauch, Dallasega, P, & Matt, 2016). The third category, Products Characteristics, is not directly related to the RAMI 4.0 but considers technological characteristics products should present. They are flexible interfaces, interoperability, and autonomy

(Guérineau , Rivest, Bricogne, Durupt, & Eynard, 2018). These characteristics, or requirements, are also compliant with a user-centered perspective of products for the Silver Market for the following reasons: product interfaces should be designed to be flexible and interoperable so that users can combine their products with other products in their context of use, enabling a set of needed or interesting functionalities. Moreover, interface flexibility is related to usability. Product use must be intuitive, easy, and minimize errors incidence. Autonomy poses as an advantageous technical trait with a direct impact on older users' autonomy: products that can be used for longer periods without recharge allow users to establish less strict daily routines (Kohlbacher, Herstatt, & Helbig, 2011).

The Enabling Technologies

As suggested earlier, attending *Industrie 4.0* digitalization principles is not a mere technological project. However, it is important to assess technological capabilities before incorporating the digitalization principles of *Industrie 4.0*, particularly when addressing the requirements for the development of smart products. Literature indicates diverse technologies that could promote digitalization through all product lifecycle stages (Rauch, Dallasega, P, & Matt, 2016; Santos, Loures, Piechnicki, & Canciglieri, 2017; Guérineau , Rivest, Bricogne, Durupt, & Eynard, 2018), Nevertheless, successfully incorporating the digitalization principles and walking towards an efficient, closed-loop, data-based product development process (Olsson & Bosch, 2013; Yoo, Clément, & Dimitris , 2016), requires combining the requirements and enabling technologies in a strategic, user-centered way. Like the requirements, the aforementioned enabler technologies represent an indication of aspects to be addressed in the *Industrie 4.0*-compliant product development process.

Again, the technologies addressed in this paper are related to the same product lifecycle stages, here called interest stages, as the previously mentioned requirements. They comprise *Industrie 4.0* pillars, thus serving as a starting point for attending the digitalization principles, and are as follows: cyber-physical systems (CPS); Internet of Things (IoT); cloud computing, required to enable the Internet of Services (IoS); standardized data formats; advanced simulations; virtual, augmented, or mixed reality (VR/AR/MR) systems; additive manufacturing; Big Data; and Artificial Intelligence (AI) (Rauch, Dallasega, P, & Matt, 2016; Santos, Loures, Piechnicki, & Canciglieri, 2017; Schmidt, et al., 2015; Nunes, Pereira, & Alves, 2017; Barth, 2013; Guérineau , Rivest, Bricogne, Durupt, & Eynard, 2018; Olsson & Bosch, 2013).

Outlook

This paper described a general conceptual framework conceived as a tool to assist in the development of smart products more adequate to elders' needs and expectations. Simultaneously, the tool would provide an adaption path of the product development process to *Industrie 4.0*-compliant. To this point, the research has been theoretical; the use of the enabling technologies to fulfill the requirements has been outlined. In order to define concrete guidelines for implementation and potential limitations, business cases and example applications are required. Hence, the next research steps include searching for partner companies, for implementation tests and conducting business cases for deriving implementation guidelines, as well as practical validation. Additionally, other successful cases of smart product development for elders should be analyzed, widening the comparative cases sample.

References

AAL Programme. (2015). S*uccess stories. 10 AAL Innovations creating real impact.* Active and Assisted Living Programme.

AAL Programme. (2016). *Innovative Technology for Active and Healthy Aging.* Active and Assisted Living Programme.

Anderl, R., & Fleischer, J. (2016). *Guideline Industrie 4.0 - Guiding principles for the implementation of Industrie 4.0 in small and medium sized businesses.* Frankfurt: VDMA.

Barth, A. (2013). 3D Experiences - Dassault Systémes 3DS Strategy to Support New Processes in Product Development and Early Customer Involvement. *Digital Product and Process Development Systems - IFIPTC 5th International Conference* (pp. 24-30). Dresden: Springer.

Beuren, H., Pereira, D., & Fagundes , A. (2016). Product-Service Systems characterization based on life cycle: Application in a real situation. *Procedia CIRP, 47*, pp. 418-423.

Coughlin, J. (2017). *The Longevity Economy: Unlocking the World's Fastest-Growing, Most Misunderstood Market* (1st ed.). Public Affairs.

European Communities. (2006). *The demographic future of Europe - from challenge to opportunity.* Directorate-General for Employment, Social Affairs and Equal Opportunities, Luxembourg.

Guérineau , B., Rivest, L., Bricogne, M., Durupt, A., & Eynard, B. (2018). Towards a Design-Method Selection Framework for Multidisciplinary Product Development. *DS 92: Proceedings of the DESIGN 2018 15th International Design Conference*, (pp. 2879-2890). Zagreb.

Haas, C. (2019). Understanding the Human-Centered Design Process. Em *Consumer Informatics and Digital Health* (pp. 145-162). Springer International.

Kagermann, H., Walhster, W., & Helbig, J. (2013). *Recommendations for implementing the strategic initiative Industrie 4.0. Final report of the Industrie 4.0 Working group.* Germany: Acatech.

Kohlbacher, F., Herstatt, C., & Helbig, J. (2011). Product Development for the Silver Market. Em *The Silver Market Phenomenon - Marketing and Innovation in the Aging Society* (2nd ed., pp. 3-19). Heidelberg: Springer.

Maslow, A. (2019). *A Theory of Human Motivation.* New Delhi: General Press India.

Nunes, M. L., Pereira, A. C., & Alves, A. C. (2017). Smart products development approaches for Industry 4.0. *Procedia Manufacturing, 13*, pp. 1215-1222.

Olsson, H. H., & Bosch, J. (2013). A Multiple-Case Study on Post-Deployment Data Usage in Software-Intensive Embedded Systems. *Proceedings: 4th Int. Conf. on Lean Enterprise Software and Systems*, (pp. 156-164). Galway.

Pahl, G., & Beitz, W. (2007). *Engineering Design - A systematic approach* (3rd ed.). Springer-Verlag.

Planinc, R., & Kampel, M. (2013). E-Health System Development based on End User Centered Design. *Proceedings: 5th Int. Conf. on eHealth, Telemedicine and Social Medicine.*

Platform Industrie 4.0. (2016). *Implementation Strategy Industrie 4.0. Report on the results of the Industrie 4.0 Platform.* Germany: Acatech.

Rauch, E., Dallasega, P, & Matt, T. (2016). The Way from Lean Product Development (LPD) to Smart Product Development (SPD). *Procedia CIRP, 50*, pp. 26-31.

Roy, J. S., Neumann, P. W., & Fels, D. I. (2016). User Centered Design Methods and their application in Older Adult Community. *International Conference on Human Interface and the Management of Information* (pp. 462-472). Toronto: Springer International.

Rozenfeld, H. (2006). *Gestã do Desenvolvimento de Produtos: Uma referência para melhoria do processo* (1st ed.). Saraiva.

Santos, K., Loures, E., Piechnicki, F., & Canciglieri, O. (2017). Opportunities Assessment of Product Development Process in Inudstry 4.0. *Procedia Manufacturing, 11*, pp. 1358-12365.

Schmidt, R., Möhring, M., Härting, R.-C., Reichstein, C., Neumaier, P., & Jozinović, P. (2015). Industry 4.0 - Potentials for Creating Smart Products: Empirical Research Results. *Proceedings of the 18th International Conference on Business Information Systems*, (pp. 16-27). Poznan.

United Nations. (2017). *World Population Aging Report.* World Health Organization, Department of Economic and Social Affairs, New York.

Wang, Y., Towara, T., & Anderl, R. (2017). Technology Landscape 4.0. Em *Transactions on Engineering Technologies* (pp. 31-45). San Francisco: Springer Nature Singapore.

World Bank. (2011). *Envelhecendo em um Brasil mais velho.* Banco Internacional para Reconstrução e Desenvolvimento, Washington.

Yoo, M. J., Clément, G., & Dimitris , K. (2016). Closed-Loop Lifecycle Management of Service and Product in the Internet of Things: Semantic Framework for Knowledge Integrations. *Sensors*, 1053-1079.

Kontakt

Carolina Sallati, M. Sc.
Laboratory for Computer Integrated Design and Manufacturing
13450-900 Santa Bárbara d'Oeste, Brazil
carolina.sallati@scpm.eng.br

Prof. Dr.-Ing. Klaus Schützer
Federal University of ABC
Avenida dos Estados, 5.001
09210-580 Santo André, Brazil
schuetzer@scpm.eng.br