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Procedia CIRP 67 (2018) 583 – 588

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11th CIRP Conference on Intelligent Computation in Manufacturing Engineering, CIRP ICME '17

Intelligent value chain management framework for customized assistive healthcare devices

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Abstract

Ageing, occurrence of work-related musculoskeletal disorders, and rising sensitivity towards the disabled are paving the way for new, customized *movement assisting devices* enabling increased mobility independence, correction of user's kinesis and prevention of diseases, combined with a constant monitoring of kinematics conditions.
This paper presents the digital double of the manufacturing, delivery and maintenance chain(s) developed for those devices, focusing on its data model, logics, services and optimization functionalities aimed at improving critical stakeholders' experiences. The proposed discussion emphasizes how a proper combination of physical and digital twins could effectively support customized manufacturing experiences in socially valuable market segments.

Peer-review under responsibility of the scientific committee of the 11th CIRP Conference on Intelligent Computation in Manufacturing Engineering

Keywords: Movement assisting devices; Value chain management; Distributed software architecture; Personalized goods

1. Introduction

Nowadays social phenomena like the fast growing of ageing population, coupled with the increased occurrence of neuro-musculoskeletal disorders as a result of working in wrong conditions and the rising sensitivity towards the disabled [1], are eliciting requirements to define hybrid solutions between advanced exoskeletons for niches of population (e.g. paralytics) and the mobility aids for the mass aging population, that aim to enable mobility independence, correction of users' kinesis and prevention of diseases.

Within the EU-funded project MovAiD, a new concept of highly personalized kineto-dynamic equipment, namely movement assisting devices (MADs), have been developed. These solutions may provide value-adding contributions to human health and safety in heterogeneous application contexts as far as they fit each user specificities and requirements [2]. Fitting results in customization, and a good customization: (i) may derive from a thorough and precise data acquisition on the reference body that needs to be *assisted* for the first MAD design; (ii) could be made robust using proper simulation tools assuring value-adding data provision for reliable product design; (iii) should involve the widest set of value-chain actors providing data on the MAD status (e.g.: during production and assembly) and receiving data for a consistent production and maintenance; (iv) is the result of continuous gathering of data along the entire MAD lifecycle, in order to adapt and tune MAD shapes and functionalities in accordance to evolving user characteristics; (v) can be better achieved combining tangible and intangible customization elements: the physical MAD modules and value-adding services enabled by data gathered from sensors embedded in the device.

"Data" is the only word in common among all these points: a proper data management infrastructure is thus an essential enabler to assure customized MAD development and delivery to identified target groups.

Peer-review under responsibility of the scientific committee of the 11th CIRP Conference on Intelligent Computation in Manufacturing Engineering
doi:10.1016/j.procir.2017.12.265

Aim of this paper is to address these challenging needs by proposing an innovative platform, extending the concepts typically concerning a Manufacturing Execution System, with aspects related to the management of the value chain of the developed devices, starting from the biometric characterization of customer (who needs the customized assisting device) till the device delivery and maintenance. Moreover, the proposed system introduces innovative solutions to drive the design and development of the specific customized products that integrate embedded sensors for collecting and managing biometric and kinetic data during leisure and professional activities.

The proposed platform is rounded by a plethora of services of different nature: some of them meant to drive the production process of the product (from the design to its maintenance), others meant to make the collected information available to the end user and to third parties (i.e. doctors, service providers, operators, etc.) who, in turn, can generate a feedback for the user (i.e. medical treatments, posture feedback and information for MADs adaptation and repairing).

The paper, after a brief state of the art on current data integration platform solutions, will present the overall System Architecture followed by the Integration Platform for the provision of the personalized value added services.

2. Background

In a production environment, operations, routes that products follow through the production system, production outcomes and failures are managed by a manufacturing execution systems (MES). According to the MES Association (MESA) definition, MES guide, initiate, respond to, and report on plant activities as they occur from order launch to finished goods [3]. MES is a manufacturing control solution that aims to streamline the flow of information about the product and related processes throughout the production line so that the accurate information is available in the right place at the right time. The product information integration and process integration are the most important factors for establishing a reliable high quality MES system [4]. MES main functionalities that can be compliant with the MovAiD solution include dispatching production units, data collection, quality management, maintenance management, operation scheduling and product tracking.

In the healthcare sector, these solutions cannot be fully and generally adopted, in particular when dealing with personalized healthcare. As stated in [5], a shift from organization-centered care to patient-centered care is needed to support patients' monitoring and offer personalized care. Moreover, exchanging data can be critical in this context. Patient's medical record contains the history of care, orders, prescriptions and test results, thus its management and exchange with other units is crucial for providing effective and high quality services [6] [7].

A solution that considers the traditional MES architecture, extending it till the inclusion of an information exchange system has been foreseen within MovAiD. The developed system has to take into consideration the following main characteristics for the MAD production:

- MAD parts and components are designed and produced to fit unique morphological characteristics of the customer, towards comfort and performance (this implies the management of both customer's record and product data);
- custom MAD kinematics combines computational geometric designs with rigid body physics to drive personalized target motion (this implies the management of production process starting from the design till the maintenance of the product);
- embedded sensing grants the acquisition of huge amount of runtime data during the life cycle of a MAD product, enabling the creation of an evolving virtual counterpart of the customized MAD and, consequently, the delivery of adapted spare parts (optimized thanks to constant feedback from the use-phase) during and beyond (through inter-generations improvement) the product life-cycle, and of user-centric services (e.g.: use-related, monitoring). This implies the integration of MES with an information management and sharing system;

MADs are based on a highly variable assembly procedure, tailored on the customer, with parts coming from a suitable value-chain capable to create a complex Kineto-Dynamics equipment in appropriate times and price (dealing with a cross-enterprise MES).

3. The MovAiD System Architecture

One-of-a-kind devices enable a perfect match and fit with specific customer requirements; life-long adaptation and tuning overly extend the offered personalization and, eventually, data gathered from sensors and transformed into knowledge towards the customer allow to enrich the offered value also with customized services. On the other side, these elements have a common requirement: effective, (quasi-) real-time, life-cycle-long and consistent data gathering and processing. The here proposed platform faces this challenge, working as a digital enabler for MovAiD MADs deployment. In order to reach the goal, the platform has to consider several elements that need to be integrated at different levels with the aim to allow, at one side, the intelligent management of the MAD production and, at the other side, the service

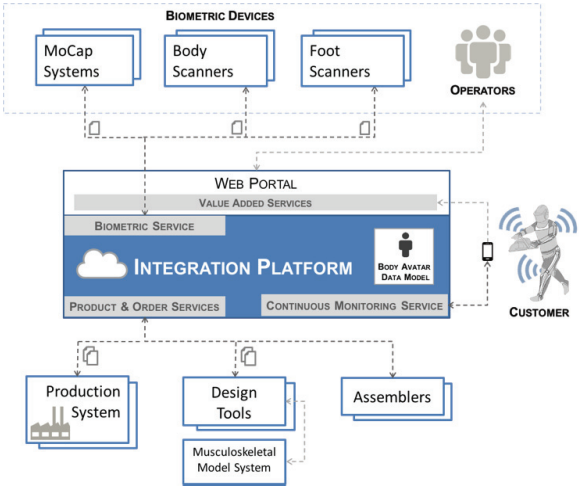

Fig. 1. Overall System Architecture: representation of components and their interactions along the MAD lifecycle.