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A Cloud-based Platform for Automated Order Processing in Additive Manufacturing

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Abstract

Additive Manufacturing (AM) is increasingly used in the industrial part production. More than almost any other manufacturing technology, AM embodies the fourth industrial revolution (Industry 4.0). Even though AM allows a nearly direct manufacturing of parts out of their CAD data, the order processing still requires a lot of manual work. This paper addresses this issue by presenting a cloud-based platform, which has the intension to integrate and automate the order processing for additively manufactured parts. In addition to facilitating the order processing of the manufacturing service provider, the platform also serves as an interface to the customer. The focus of the platform is on an automation of the order acceptance, the offer calculation, and the part screening for the identification of appropriate AM parts. The paper builds an exemplary Industry 4.0 showcase by illustrating concepts and methods for an automation of the order processing and introducing the architecture of the implemented system. This includes web-based services for the management of parts and orders as well as an integrated analysis of geometry data for checking of manufacturability and quotation costing. The evaluation examines the efficiency and effectiveness of the platform.

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Keywords: cloud platform ; automated order processing ; additive manufacturing (AM)

1. Introduction

Additive Manufacturing (AM) represents the fourth industrial revolution (Industry 4.0) more than any other manufacturing technology. AM allows a nearly direct manufacturing of parts out of their CAD data by building up parts layer by layer based on given 3D geometry data [1,2]. Within this paper, the focus is given to selective laser melting (SLM), which is the mainly used AM technology for metallic components.

One of the key components of Industry 4.0 is the Internet of Things and Services (IoTS), which enables services providers to offer their services via the internet [3–5]. The cloud platform, which is presented in this paper, connects the idea of an internet-based service platform with additive manufacturing. To have a clear understanding about the term of a cloud platform in the context of this paper, we define the term of a *cloud platform for manufacturing* as follows:

Definition 1 *Cloud-based Manufacturing Platform* describes a software application, which integrates and crosslinks several digital services for the manufacturing of physical goods (parts or components) in one web-based environment. It is hosted in the cloud (on web servers) and provides access to user or programming interfaces (for the customer and the service provider) via the internet.

Although AM is close to the principles of Industry 4.0, the order processing still requires a lot of manual work. Thus, one main objective of the integrated cloud platform is an automation of the order processing. Beside of presenting the workflow, concepts, and features of the implemented platform, the focus of the paper is given to an automated, web-based quotation costing, order acceptance, and part screening. The order acceptance process includes a checking of a part's geometry on manufacturing restrictions and design guidelines. A major difficulty in implementing AM is the

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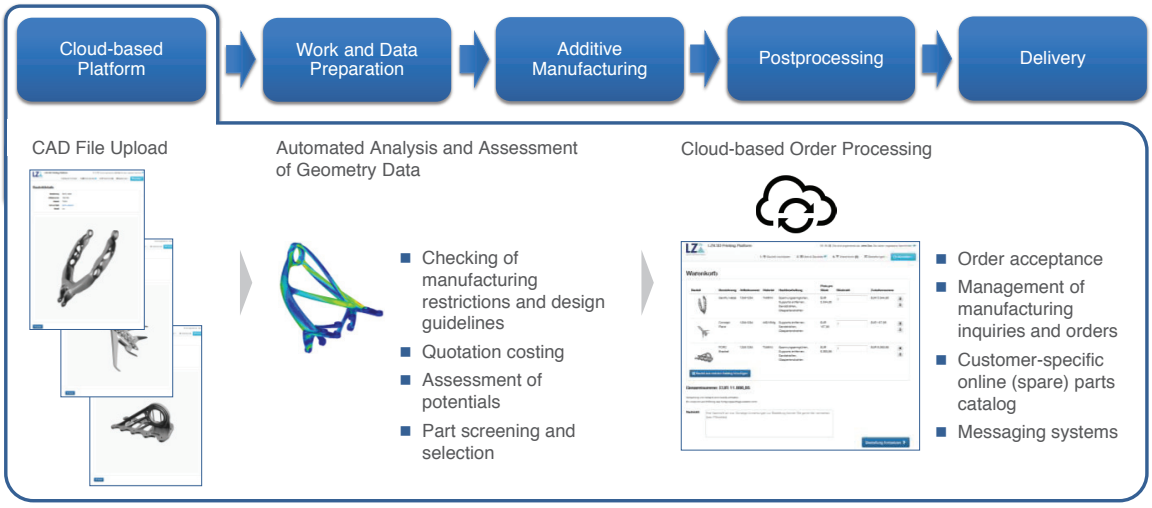

Fig. 1. Content and features of the cloud-based additive manufacturing platform (figure of optimized bracket: [6])

identification of appropriate parts. Therefore, this paper presents an easy-to-use part screening service, which is integrated into the platform.

The paper is structured as follows: Section 2 presents the related work and gives further background information. Section 3 describes the developed platform with a focus on methods and algorithms for an automated quotation costing, design checking, and part screening. Section 4 introduces the system's architecture and implementation. Section 5 evaluates the efficiency and effectiveness of the platform. Section 6 gives a conclusion and outlook.

2. Background and Related Work

In recent times, the first AM service providers offer the option to place orders online [7]. Examples for such commercial online portals are: i.materialise[1], Shapeways[2], and Sculpteo[3]. To the best of our knowledge, an integrated assessment of potentials (and part screening) is so far not state of the art. As introduced in Section 1, this paper presents an integrated approach for an automation of the quotation costing, checking of manufacturability, and part screening. The related work is presented in the following:

A comprehensive overview of published cost models for AM technologies is presented in [8]. Grund and Schmidt present analytical cost models for SLM in their theses [9,10]. The quotation costing, which is presented in this paper, adapts and expands these approaches to a generic model, which automatically calculates the unit costs for a part. Cost drivers, such as the build height of a part or the capacity utilization of a build job, are determined by a statistical method.

In order to ensure a fault-free AM process and provide required qualities (e.g. shape and position tolerances), certain manufacturing restrictions and design guidelines have to be considered. In recent research, process- and material-specific guideline catalogs have been developed [11–15]. We analyzed existing design guideline catalogs to select these guidelines, which allow an automated checking based on a part's STL file: part dimensions, wall thicknesses, gap dimensions, cylinder, and borehole diameters. For these guidelines checking algorithms have been developed.

Several different part selection and decision support methodologies have been developed in the past [10,16–18]. However, all these methods have in common that their application requires high manual effort and a lot of user input. This paper addresses this issue by presenting an automated part screening methodology, which tries to fulfil the requirements to be efficient, effective, transparent, and easy to use. Basis of the part screening is an automated cost calculation and comparison with conventional manufacturing technologies (milling and casting).

3. A Cloud-based Platform for Additive Manufacturing

The aim of the platform is an automation of the order processing for additively manufactured parts in a web-based environment. Fig. 1 gives an overview of the content and the features of the presented cloud platform. On the one hand the platform builds the communication interface between the customer and the manufacturing service provider. On the other hand it supports the service provider in the processing of orders and inquiries.

3.1. Workflow and Features

The customer can upload the geometry data of a part via the web browser by an online form (see Fig. 2). Afterwards, the geometry is analyzed and an offer is automatically calculated (on the web server). On basis of the offer, the customer can place a manufacturing order. Manufacturing restrictions and design guidelines are checked to decide, whether an order can be accepted or must be rejected.

[1] https://i.materialise.com/, Accessed: Dec. 2016
[2] http://www.shapeways.com/, Accessed: Dec. 2016
[3] http://www.sculpteo.com/, Accessed: Dec. 2016