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Bridging Gaps in Cloud Manufacturing with 3D Printing

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Abstract: In order to keep up with the flexibility and cost-efficiency requirements, the manufacturing industry has begun a transformation process towards a service-oriented production approach. This approach is in line with the cloud manufacturing paradigm that applies established concepts from cloud computing to the manufacturing domain. Although the cloud manufacturing paradigm provides promising concepts for a flexible manufacturing industry, it still exposes several challenges. One of the most important challenges is the recovery from production failures and delays. Due to the physical configuration and transportation overhead in the manufacturing domain, it is often not possible to quickly replace one production facility with another one. To bridge the gap of these production delays, we propose the integration of additive manufacturing technologies tightly into cloud manufacturing processes to ensure the continuity of the production processes.

Keywords: Cloud Manufacturing, Additive Manufacturing, 3D Printing, Industry 4.0

1 Introduction

In the last couple of years, the manufacturing industry has begun a fundamental transformation from static production processes towards flexible network-based ones. Due to the increasing flexibility of customer requests towards quantity, but also customizability of goods, the manufacturing industry needs to continuously adapt the production processes to keep up with these demands [TST12]. Furthermore, the manufacturing industry also needs to stay competitive towards competitors and therefore aims at maximizing the usage of their production facilities.

One promising approach to tackle these challenges is to adopt the successful concepts from the field of cloud computing and transform the manufacturing capabilities from static building blocks into flexible services. Flexible services can then be leased on-demand, in a utility-like manner and allow to compose dynamic production processes that can be adapted to the ever-changing customer demands. These concepts have been introduced as cloud manufacturing [Xu12] and although the theoretical foundation for cloud manufacturing is present [Sc14], there are still several challenges for adopting these concepts in real-world scenarios. To resolve these challenges and to provide a holistic solution approach, the CREMA research project [Sc16] realizes a framework to coordinate the services across numerous manufacturing companies to realize vast manufacturing networks. These manufacturing networks allow a dynamic and efficient realization of production processes by orchestrating individual manufacturing capabilities in a service oriented manner, as described in detail in Section 2.

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Although the CREMA framework provides a promising solution for most application scenarios, there are still scenarios that cannot be covered with the current approach. This specifically applies to scenarios, where one specialized service fails, e.g., a manufacturing machine failure or shortage on starting material, and cannot be replaced by other services. In such a situation, the CREMA framework currently needs to wait until the service is mended again or another identical service becomes available within the manufacturing network. In order to eliminate the resulting production delay, the concept of additive manufacturing is predestined to fill the gap [KLN98]. Modern additive manufacturing techniques are capable of producing objects following any arbitrary shape and expose similar quality levels as traditionally produced objects.

Despite the fact that current additive manufacturing machines, e.g., 3D printers, cannot cope with the production makespan of specialized machines, they excel at the almost negligible setting-up time for new product shapes. This makes these machines a perfect fit to support the transition from traditional production processes towards utility based ones [KPH14, Wu15].

In this paper, we are going to provide more detailed information about the CREMA framework and argue how additive manufacturing technologies can become a catalyst for the cloud manufacturing era.

2 Framework Overview

In order to discuss the CREMA framework, we consider an exemplary scenario from the manufacturing domain, as shown in Figure 1. In this process, Company 1 produces a product, based on parts from two suppliers. These parts are then assembled in their plant in Germany before they get their final polish in the plant in the United Kingdom. To realize the production process, the CREMA framework decomposes the overall process into individual steps, which are represented by virtualized services.

At the beginning of the process realization phase, a process designer of Company 1 decomposes the production process into virtualized services. After the decomposition, the process designer queries the Manufacturing Network to find suitable services. While the latter two services are already fixed due to the fact that Company 1 wants to use their own production capabilities, the supplier steps are chosen in an ad-hoc manner, based on the availability, price and quality aspects. After the initialization and configuration phase is finished, the CREMA framework takes care of the instantiation of the production process, i.e., triggers the real world manufacturing activities and takes care of the billings aspects [Sc16].

Whenever a problem, like a production failure or transportation delay, occurs, the CREMA framework needs to update the production process. This is done by finding new services on the Manufacturing Network, which are able to replace the failing ones. For our example scenario, we assume that Supplier 2 is not able to deliver the required parts in time. In this situation, the CREMA framework queries the Manufacturing Network to find a suitable replacement on short notice. While this replacement operation can be solved quickly in a cloud computing scenario, it is more complex for a cloud manufacturing one.

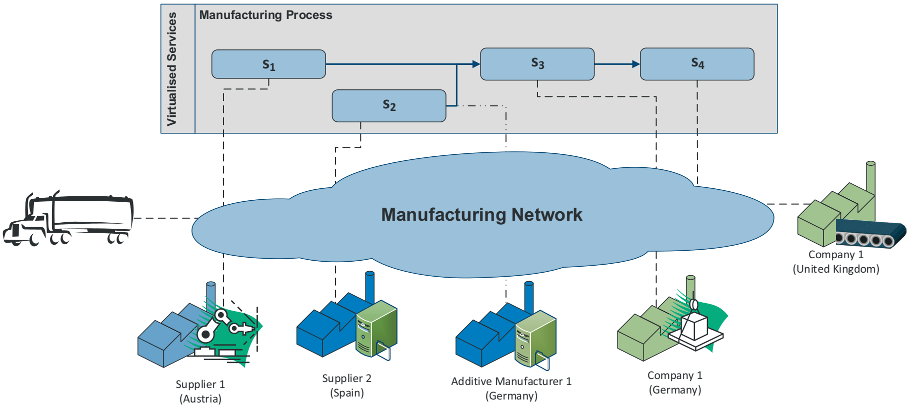

Fig. 1: Exemplary Scenario

In the manufacturing domain, we also have to consider the transport aspects to move the goods from one location to another as well as the long setup time to start the production of a new product shape. Although the Manufacturing Network offers numerous services, which may be suitable as a replacement, it is rather unlikely to find one which is willing to produce a small quantity of goods and is geographically near the plant of Company 1 in Germany that requires the parts, to minimize the transport routes.

In this situation, additive manufacturing services, like the UPS 3D printing service[4] or 3D Hubs[5], provide promising solutions for a short term replacement. These service providers offer printing services in a service oriented manner and can be easily integrated into the existing Manufacturing Network. Although the price per unit is typically higher for 3D printing services, compare to traditional manufacturing techniques, these services do not require long setup times and do not care about the quantity of parts they produce. Furthermore, the already existing printing providers offer their services at multiple geographic locations, which makes it easy to find a nearby replacement service, such as the Additive Manufacturer 1 in our exemplary scenario.

3 Outlook

The previous section sketches one of the major challenges for the widespread implementation of cloud manufacturing, namely the slow recovery possibilities whenever a failure or a delay occurs within one specific production step.

To mitigate this, we propose the integration of additive manufacturing techniques into cloud manufacturing paradigm. This allows companies to be more flexible in terms of replacing faulty services to mitigate negative effects on their production processes.

[4] `https://www.theupsstore.com/print/3d-printing`
[5] `https://www.3dhubs.com`

Our exemplary scenario shows, that additive manufacturing may be the most promising solution to bridge gaps in cloud manufacturing, these technologies can be also used to foster the individualization of products. Due to the fact that 3D printers require hardly any physical setup time, they are applicable to produce very small quantities of products, which is not feasible with traditional production approaches.

Although additive manufacturing seems to be the perfect solution for cloud manufacturing, there are still several challenges that need to be solved before they can be integrated in the same manner as traditional manufacturing machines. The most prominent challenge is the quality of the printed products. While some 3D printers are capable of printing products in a high quality, there are still numerous printers which cannot provide the required quality. Additionally, each printed object is unique and requires individual quality control. Here it is necessary to develop effective as well as efficient quality assurance techniques, which are suitable for this individual characteristic of manufacturing products.

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