C-MARS-ABM: A deployment approach for cloud manufacturing

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Abstract. Cloud manufacturing is defined as a resource sharing paradigm that provides on-demand access to a pool of manufacturing resources and capabilities aimed at utilising geographically dispersed manufacturing resources in a service-oriented manner. These services are deployed via the Industrial Internet of Things and its underlying IT infrastructure, architecture models, as well as data and information exchange protocols and standards. In this context, interoperability has been identified to be a key enabler for implementing such vertically or horizontally integrated cyber-physical systems for production engineering. Previously, the authors proposed an interoperability framework called C-MARS (Cloud Manufacturing Resource Sharing System) to enable error free and non-ambiguous information transfer between the various components and layers of a typical cloud manufacturing system. The main contribution of this paper concerns the identification of the key process parameters for deploying cloud manufacturing processes via a generic and costing-based operation and deployment model (CMARS-ABM) used to simulate interoperable cloud-based manufacturing scenarios for parts of different complexity, varying production numbers, and service composition setups typical to SMEs of varying sizes. Initial results confirm that Cloud Manufacturing is not a one-size-fits-all solution, and that there are indeed a number of driving parameters that need to be analysed to determine whether or not an investment in cloud manufacturing may be financially beneficial and advisable given a specific scenario.

Keywords. Cloud Manufacturing, C-MARS, C-MARS-ABM, Interoperability.

1. Introduction

Cloud Manufacturing was introduced as the new manufacturing service-oriented paradigm. This paradigm utilises cloud computing technology along with Internet-of-things and state-of-the-art manufacturing technologies to integrate manufacturing resources and capabilities to offer on-demand, reliable and affordable manufacturing services for the en-

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tire manufacturing product life cycle [14]. The manufacturing industry is gradually moving to view resources as services that can be used on an ad-hoc basis [9]. As services require more information compared to the traditional view of dedicated manufacturing resources [10] , informatisation of manufacturing is emerging as a strategic step for realising this new paradigm [5].

In order to bring about this change, various information technologies including Internet-of-Things and cloud computing are being aggregated [7, 4]. The informatisation is an enhancement and collaborative approach that can expand competitiveness of small and medium size manufacturing enterprises (SMEs) [8]. They will gain the ability to provide services to larger and more complex jobs which would allow steps towards globalisation of economy, resources and rapid development of advanced manufacturing, information, computer and management technologies [11]. The resulting environment would allow various application services to be provided, e.g. collaborative design services, digital manufacturing services and B2B eCommerce services [3].

Interoperability, today, is not implemented at a sufficient level for cloud manufacturing; there is a lack of standardised methodology of information exchange between different cloud users [2, 12, 13]. Consequently, interoperable cloud manufacturing framework was introduced by the authors[6] for CNC machining applications, integrating the essential components that to enable the cloud manufacturing system(C-MARS). The framework is shown in Fig. 1. In this paper, the proposed framework is compared with a non-interoperable framework for cloud manufacturing that is reliant on the traditional CAD-CAM-Post Processor-CNC chain for machining. Through the development of an activity-based model for C-MARS-ABM illustrating both the interoperable and non-interoperable approaches, the driving parameters for determination of the appropriate level of interoperability are explored.

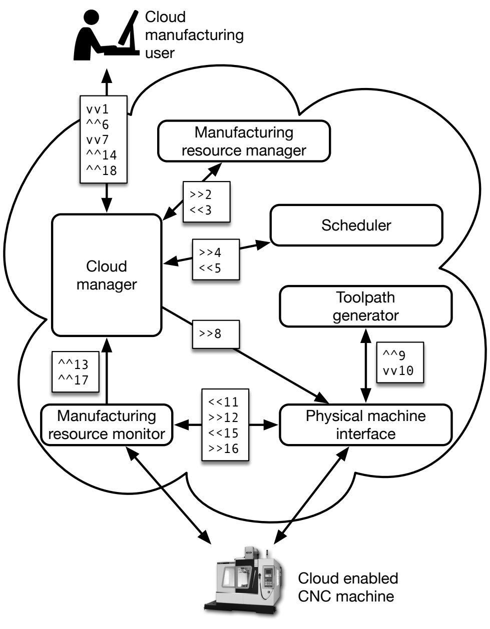

Figure 1. CMARS Framework[6]

2. C-MARS-ABM development

The C-MARS framework developed in [6], is mainly focused on CNC machining of prismatic parts. In order to compare the interoperable approach to the non-interoperable for creating a machining cloud manufacturing service, two activity based models are defined, illustrating the deploying approach of the manufacturing life-cycle from the interoperability perspective.

2.1. Interoperable approach

The interoperable approach to cloud manufacturing is enabled through the use of a standardised high level machining language that can describe part manufacturing requirements in a manner interpretable by a wide variety of resources. For C-MARS, the ISO14649 suite of standards [1] are used as they provide the necessary level of abstraction to describe the manufacturing requirements of prismatic parts. As shown in Figure 2, the interoperable approach is defined based on 23 various activities assigned to four main entities; Process plan agent, C-MARS User, C-MARS agent, and C-MARS provider. The machining process life-cycle is initiated when the design file is uploaded to the C-MARS web interface (A1.1), passed to design file interpretation (A1.2) and machining criteria identification (A1.3) by the C-MARS Agent, then follows the activity path until the final machine part is delivered to the designated destination (A1.23).

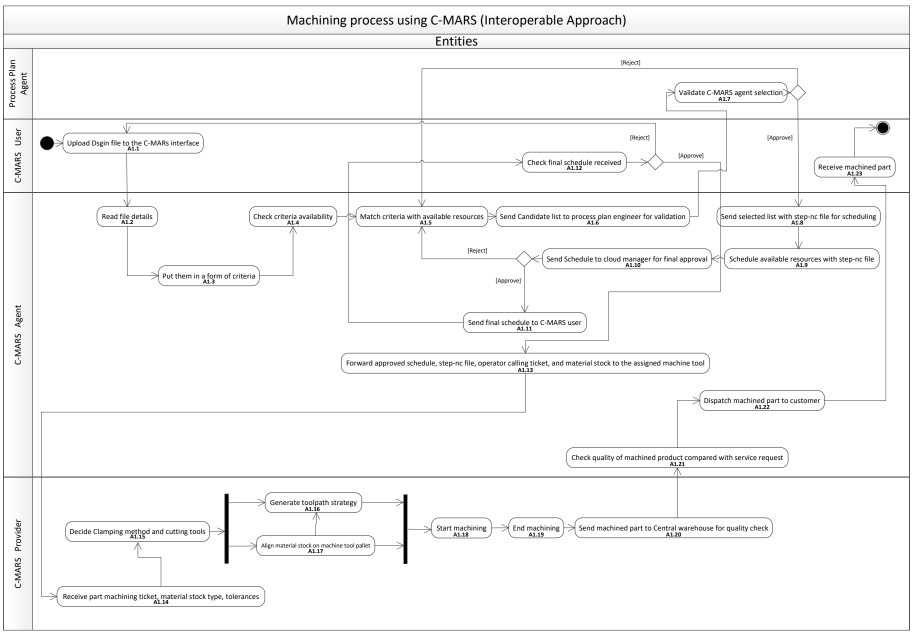

Figure 2. CMARS Interoperable approach

2.2. *Non-interoperable approach*

Alternatively, for the non-interoperable approach, Figure 3 illustrates 21 procedural machining activities, similarly to the traditional manufacturing CAx processes, utilising the legacy G&M codes for machining process execution. The service is initiated by filling in a service request form by the C-MARS agent (B1.1). Consequently, the C-MARS agent identifies the required manufacturing resources (B1.2) and allocate the available C-MARS resources (B1.3), accordingly the C-MARS machining of the non-interoperable approach, following on the path illustrated to the service acquired activity (B1.21)

3. Simulation and sensitivity analysis

Based on the activity based model developed CMARS-ABM for both approaches, the Monte Carlo simulation technique is utilised to compose feasible sets of C-MARS manufacturing clouds and compare the effectiveness through cost estimation. Each activity is thus identified explicitly in a form of costing formula based on parameters such as number of orders, quantity of parts per order, complexity of process planning and post processing, the size of the SMEs, the number of the companies involved in the cloud and so on in three categories as reported in table 1. The formulae are then used to calculate the total cloud cost based on sampling the random variables.

The preliminary results of the simulation are shown in Figure 4. The figure shows that the order size per cloud member SME and the process planning time required for each part are the two main determinants for selection of the interoperable framework over a cloud solution based on the traditional CAD/CAM/CNC chain.

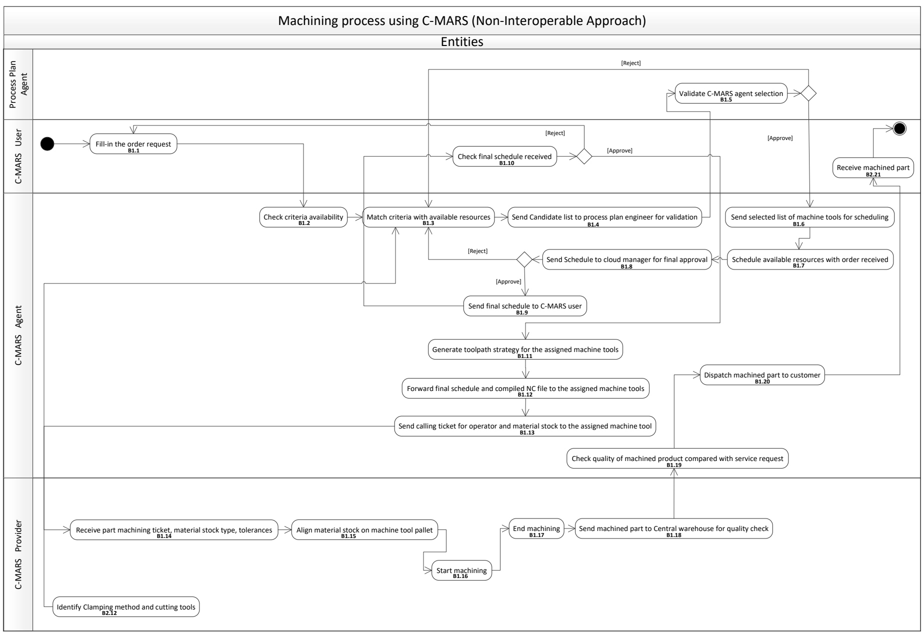

Figure 3. CMARS Non-Interoperable approach

Table 1. The list of parameters used in Monte Carlo simulation of CMARS-ABM

Category	Parameter	Description
Orders	Orders	Number of orders received every day by the cloud system
	Quantity	The quantity of parts required in an order
	Time for machining	How long it takes to machine one part
	Clamping decision time	The amount of time it takes to design workholding
Service providers	Size	How many employees are there in each cloud member SME
	Operators	How many employees are machine operators
	SME members	How many SMEs are involved in the cloud
	Machine tools	Number of machine tools deployed in an SME
	Experts	The number of people who are CAM experts in the SME
	Shifts	The number of shifts in which the SME is active
Expertise	PP time	Time to process plan a manufacturing job

4. Conclusion and Future work

This study has shown that under certain circumstances, investment in a new interoperable framework for establishing a CNC machining cloud is beneficial over using the traditional CAD/CAM/CNC chain for creating the cloud. In particular, Figure 4(a) shows that if the cloud is producing a large number of different orders in relation to the number of SME members, the use of the interoperable framework would be cost effective. In a similar manner, Figure 4(b) shows that the complexity of the jobs handled by the cloud also have a major bearing on whether the additional investment required to deploy an interoperable standard such as STEP-NC would be cost effective. For a cloud that handles very simple parts as indicated by a process planning time of less than 15 minutes per part, the traditional CAD/CAM/CNC approach or the direct use of G&M codes would be more economical than investing in the new platform. For highly complex parts, on the other hand, the investment is cost effective. Overall, the preliminary studies indicate that for a CNC machining cloud, the variety and complexity of the parts should be significant to warrant the investment in a new interoperable manufacturing framework.

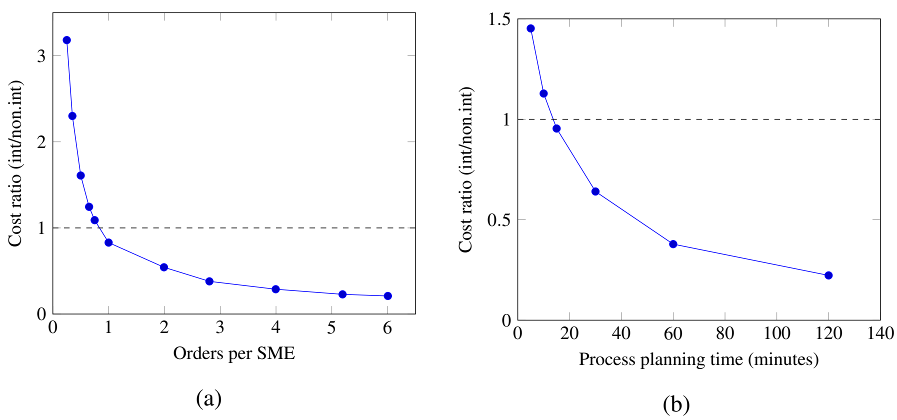

Figure 4. Preliminary analysis of simulation results

To follow this preliminary analysis, as part of their future work, the authors will simulate a number of industrial cases and use Taguchi orthogonal array as well as full factorial analysis where appropriate to determine the significance and dependence of various parameters within CMARS-ABM.

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