The 24th CIRP Conference on Life Cycle Engineering

Operation Mode Study in Cloud Manufacturing Ecosystem

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Abstract

With cloud manufacturing and its shared big-data, the life-cycle management of the massive distributed manufacturing resources can be considered as an ecosystem, in which every entity makes their own decisions depend on the enriched information, which will affect the life cycle of the resources and the overall industry states. In this paper, an original operation mode with three extensions are proposed to describe the life cycle vicissitude of each resource. An agent-based model was designed to simulate the ecosystem modes from the very beginning, and the results show that the ecosystem has: 1) shorter job queue length and lower resource idle rate with incubation mode; 2) a little shorter job queue length and fewer amount of registered resource with outsourcing mode; 3) the fewest amount of registered resource but a little higher resource idle rate with metabolism mode.

Keywords: Cloud manufacturing ecosystem; decision-making; operation mode; ecosystem evolution; agent-based simulation

1. Introduction

Manufacturing activities consume kinds of resources (e.g. material, equipment, manpower, nature resource), which will lead to substantial environmental issues. Arrangement of these resources to collaborate a manufacturing process is one of feasible approaches to reduce the idle rate of resources; the concept of cloud manufacturing \([1, 2]\) provides an operating framework to realize the arrangement. However, the relationship among entities in a cloud manufacturing system become more complicated than that in current manufacturing systems, since the integration of advanced technologies makes it possible for individual to make decisions depend on enriched information. Entities' preferences stimulate the emergence of good resource arrangement pattern to support operation mode in the cloud manufacturing ecosystem. Hence, it’s important to identify a suitable operation mode to meet most entities’ preferences and to optimize the resources management.

In this paper, an original operation mode is designed to describe the basic decision-makings of entities in cloud manufacturing ecosystem, and then three extensions are proposed, namely metabolism mode, incubation mode and outsourcing mode. Finally, an experiment to validate these synthetic operation modes is designed, which uses an agent-based simulation method.

2. Review on cloud manufacturing and simulation

Resource consumption in manufacturing activities is inevitable, waste or idle of these resources are pervasive in current manufacturing systems \([3]\). Manufacturing innovation which driven by effective utilization is one key consideration of overcoming the environmental burden \([4, 5]\). This paper is scoped with the designs of mode to generate manufacturing service, which is an arrangement of resources on the cloud manufacturing platform, and to manage the overall manufacturing resources in high quality level at the meantime.

Platform operator can manage manufacturing service, which encapsulated distributed manufacturing resources intensively with appropriate business model \([2]\). Modular and multi-layer architecture are the most common approaches to build a cloud manufacturing platform or system framework \([6, 7]\). Lv used the list of views to depict this multi-layer architecture \([8]\). Servitization is the key philosophy to operate...
cloud manufacturing [1]. A service can be created statically which comes along with a provider [6], or can be created dynamically according to task pattern, such method as ‘Multi-Composition for Each Task’ [9] that combines incompetent service as a whole. A service can also be created by AI planning-based automatic composition framework [10].

Simulation approach has been widely used in manufacturing systems on operations planning and scheduling, real-time control, operating policies, performance analysis [11]. In operating policies field, scheduling policies can be tested with simulation performance under given machine conditions [12], machine segmentation policies can be simulated in a combined MRP and Kanban production system [13]. Mourtzis et al. [14] explored a series of simulation-based solutions in industrial practices and concluded that research trends are in Internet- and cloud-based situations.

3. Cloud manufacturing ecosystem

Before introducing the cloud manufacturing ecosystem, we specify some basic definitions as following:

- **Provider**: the entity that provides resources;
- **Resource**: the basic task processing object with renewable capacity and unique type;
- **Demander**: the entity that publishes order that contains a set of tasks;
- **Task**: the basic object needs to be processed with resource-type cooperation;
- **Task-part**: virtual resource-type segmentation unit of one task as squares in Fig. 4;
- **Service-call**: the basic object that needs to be processed with both resource-type and resource-capacity cooperation;
- **Service**: the perform result of a service-call, a set of tasks;
- **Platform**: the place where individual interact with others;
- **Resource-type cooperation**: specific resources to process a service-call simultaneously as in Fig. 3.
- **Resource-capacity cooperation**: same type of resources to process a service-call with both resource-type and resource-capacity cooperation;

Since demander and provider arrive successively, there is no upper bound for the subscripts (i, j, k, l, a). To scope our research, we make some assumptions as follows for the original mode.

- **Operator** of the ecosystem starts from the very beginning that no demander or provider was registered;
- **Each single task** should be assembled by its task-parts, and these parts should be processed simultaneously;
- **The quality of product** is determined by the worst quality of the selected resource;
- **Resource** are renewable that the available capacity will be returned to when the process procedure finished;
- **Provider** can only schedule task-parts that in inactive status.

3.2. Master plan for original and extended modes

In original mode, ecosystem starts with void, then there comes the registration of provider and demander. A single order consists of a set \( T = \{ t_1, t_2, \ldots \} \) of tasks, which are interrelated by kinds of constraints. First, precedence constraints force task \( t_{ij} \) not to be started before all its immediate predecessors in \( P_{ij} \). Second, performing the tasks requires resources with limited capacities. Third, resource-type cooperation ensures all the task-parts should in active status. A single resource \( (mr_k) \) can only belongs to one type. While being processed, task \( t_{ij} \) requires \( q_{a,i,j} \) units capacity of the resources in type \( a \in A_{ik} \) during every period of its non-
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