A cloud based architecture for Automatic Feature Recognition in Distributed manufacturing environment

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Abstract

The recent manufacturing encapsulates the globally distributed enterprise resources which requires advanced technologies i.e., Internet of things, cloud computing, semantic web and service-oriented technologies to establish the effective global manufacturing network. This hinders issues of heterogeneous product information related to multi-disciplinary domains, which make the knowledge within documents irreconcilable. This paper presents, an automatic feature recognition based cloud service platform for a distributed manufacturing environment, which enables the networks to enhance the interoperability by seamless exchange of information. The proposed architecture acts as an integrated approach that consists of a three layers namely physical resource layer, local server layer, and cloud layer as services to meet the requirements of real time distributed manufacturing environment. Moreover, the most effective tools and techniques such as transfer protocols, ontology, heuristics, meta-heuristics, World Wide Web (www), and extensible markup language (xml) has been used to develop and implement the proposed cloud manufacturing platform. The integrated solution proposed in this paper can push forward this new paradigm from concept to practice for optimal service recommendation.

Keywords
Automatic feature recognition, distributed manufacturing, cloud services optimization, knowledge management, Ontology.

1. Introduction

Today's advanced manufacturing enterprises are becoming worldwide competitors through collaboration, innovation, servitisation and sustainability by transforming the current scenario of production-oriented manufacturing to service-oriented manufacturing now (Li et al. 2012). Cloud computing, Internet of things, semantic web and service-oriented technologies have been identified as key business technology trends that will reshape enterprises to reach the world market. The success of many world market manufacturers relies on the distribution of their manufacturing capacities over the globe. With a worldwide integration of their distributed product development processes and manufacturing operations, they are realizing and taking advantage of the many benefits of resource coordination and sharing (Valilai and Houshmand. 2013). How to integrate all these new applications and information technologies in a single platform is the expected problem to address in order to establish world manufacturing networks of all distributed resources. The objective of this paper is to present a new platform based on current solutions to solve problems of integration of distributed manufacturing networks through cloud computing.

Cloud Computing (CC) is a concept that enables ubiquitous and on-demand access to a shared pool of computing resources as services in a convenient pay-as-you-use/go mode with high reliability and scalability (Mell, P. and Grance, T. 2009). Xu (2012) presented the concept of offering computer resources as services can be adopted in manufacturing, with manufacturing resources being offered as different services, i.e., Platform-as-a-Service (PaaS), Infrastructure-as-a-Service (IaaS), and Software-as-a-Service (SaaS). The most prominent and promising feature of Cloud in manufacturing context is the seamless and convenient sharing of a variety of different kinds of distributed manufacturing resources, realising the idea of Manufacturing-as-a-Service (MaaS), Design-as-a-Service (DaaS), and Machining-as-a-Service (MCaaS). Its working principle is for providers to effectively organise and encapsulate manufacturing resources and capabilities and make them available as services to consumers in an operator-run manufacturing Cloud. The main advantage for enterprises in cloud based solution is that almost no local IT resource investment is required (Helo et al. 2014).

The objective of this paper is to present a new approach for solve integration and collaboration problems of distributed resources in cloud platform. The ontology-semantic rule based automatic feature recognition is the proposed novel approach, which have the capability to address these issues on implementation in cloud platforms. This paper has also presented enough procedures and clear structures for supporting the proposed solution to be practicable.

The rest of the paper is organized as follows: Section 2 reviews related technologies and back ground work. Section 3 presents the over view of proposed architecture and requirements. Section 4 discusses the cloud based automatic feature recognition framework in a distributed manufacturing environment. Conclusions are given in Section 5.

2. Literature review

The rapidly growing needs and opportunities of today's global market require a high level of interoperability in data systems to integrate the diverse information systems to share knowledge and collaboration among manufacturing enterprises (Helo et al. 2014). This includes maintaining the business partnership with the clients and resource providers in this dynamic environment on a day-to-day basis. Some research works related to both cloud based distributed manufacturing as well as ontology based automatic feature recognition techniques are reviewed in this paper as follows.

2.1. Cloud based platforms for the integration of distributed manufacturing resources

Valilai, O.F., and Houshmand, M., (2013 and 2014), developed an integrated and collaborative manufacturing platform named XMLAYMOD by using a service-oriented approach of cloud computing paradigm. The product data integration based on the STEP standard is maintained for supporting XML data structures through this approach. In the latest works of the authors, proposes a new manufacturing platform called STRATUS Cloud, based on the cloud manufacturing paradigm to fulfil the requirements of global manufacturing platform especially in enabling the global manufacturing for adoption of optimal solution systems. The STRATUS Cloud inherits capabilities from the recent authors' researches such as collaboration support of distributed manufacturing agents over the globe and the integration of the manufacturing operation based on the STEP standard while extending its application and fulfilling STEP's limitations. The STRATUS Cloud proposes a contribution for enabling the adoption of the optimal solutions through manufacturing processes. This contribution is achieved via a manufacturing cloud reconciled with the proposed platform structure.

Wu, et al. (2015), Cloud-based design manufacturing (CBDM) refers to a service-oriented networked product development model in which service consumers are enabled to configure, select, and utilize customized product realization resources and services ranging from computer-aided engineering software to reconfigurable manufacturing systems. To justify the conclusion that CBDM can be considered as a new paradigm that is anticipated to drive digital manufacturing and design innovation, we present the development of a smart delivery drone as an idealized CBDM example scenario and propose a corresponding CBDM system architecture that incorporates CBDM-based design processes, integrated manufacturing services, information and supply chain management in a holistic sense.

Chen, et al. (2015), proposes a novel cloud manufacturing framework (CMF) with auto-scaling capability (called CMFAS) aimed at providing a systematic and rapid development approach for building CMSs. The proposed CMFAS contains a cloud-based architecture which can transform single-user manufacturing functions (MFs) into cloud services that can be accessed by many users simultaneously. Also, a user-acceptable time-based scaling algorithm is designed so that the CMFAS can automatically perform scale-out or scale-in on the number of virtual machines (VMs) according to the user arrival rate, while confining the average service time for a user to be less than a specified user-acceptable time using a minimum number of VMs. Finally, we develop an Ontology Inference Cloud Service (OICS) for machine tools based on the CMFAS and deploy it on a public cloud platform for conducting integrated tests. Testing results show that the OICS can successfully recommend proper machine tools and cutting tools for machining tasks, and the proposed scaling algorithm outperforms traditional CPU-load-based scaling algorithms in terms of a smaller average service time for a user (i.e. quicker processing time) and a smaller number of created VMs (i.e. less cost of leasing cloud resources). The proposed CMFAS, together with its detailed designs, can serve as a useful reference approach for systematically and rapidly building CMSs for the machining industry.

Mourad, M., et al. (2016), The emerging cloud paradigm has a prominent effect on manufacturing. The move from hardware bound systems to requirements based service provision is enabling the transition to cloud manufacturing. A networked manufacturing service provision system requires vast amounts of information to be exchanged in a non-ambiguous and timely manner to meet production requirements. In this paper, interoperability is identified as a key enabler for cloud manufacturing and a framework for realisation of interoperability across heterogeneous computer aided manufacturing systems is proposed. Using this framework, manufacturing resources can be shared by a large number of clients based on requirements and priorities

Lin, L.F., et al. (2011), presents a constructive, two-level knowledge modelling approach to systematically develop manufacturing Ontologies using both software engineering and Semantic Web paradigms. The UML/OCL (Unified Modeling Language/Object Constraint Language)-based object modelling is used first to serve as a graphical and structured basis for conceptual communication between domain experts and knowledge engineers. The OWL/SWRL (Web Ontology Language/Semantic Web Rule Language)-based ontology modelling then extends the UML/OCL-based object models with added semantics using a progressive, semantics-oriented knowledge acquisition method.

Lu, Y. and Xu, X. (2017), develop an integrated networked environment, allowing fast resource allocation for a given service request, subject to governance policies, resource access policies, resource availability information. The research challenge in this is to explore a feasible service composition method that facilitates easy mapping between service requests and manufacturing resources based on restrictive rule sets in the cloud and availability information about a resource. It examines knowledge-based service composition and adaptive resource planning in a cloud manufacturing environment. The research work in this paper analyses the relevant research challenges, proposes a practical approach and implements the solution in the form of a web-based system. The proposed system utilises distributed knowledge for intelligent service composition and adaptive resource planning.

Adamson et al. (2016) present a feature-based manufacturing for adaptive equipment control and resource-task matching in distributed and collaborative CPS manufacturing environments is presented. The concept has a product perspective and builds on the combination of product manufacturing features and event-driven Function Blocks (FB) of the IEC 61499 standard. Distributed control is realised through the use of networked and smart FB decision modules, enabling the performance of collaborative run-time manufacturing activities according to actual manufacturing conditions. A feature-based information framework supporting the matching of manufacturing resources and tasks, as well as the feature-FB control concept, and a demonstration with a cyber-physical robot application, are presented.

Table 1. Current researches of cloud based distributed manufacturing

Researchers	Support collaboration in DME	Cloud technologies	Service optimization	Automatic Feature Recognition	Ontology
Adamson, G. et al. (2016)	√	√			
Lin, L.F., et al. (2011)		√			√
Lu, Y. and Xu, X. (2017)	√				√
Mourad, M., et al. (2016)	√	√			
Valilai, O.F. and Houshmand, M. (2013)	√	√			
Valilai, O.F. and Houshmand, M. (2014)	√	√	√		
Wang, Q., and Yu, X. (2014)				√	√
Wu, D., et al. (2015)		√			√
Wu, Y., et al. (2015)		√		√	
Zhang, Y., et al. (2016)				√	√

2.2. Automatic feature recognition mechanisms

In recent decades, an intense research has been carried out on automatic feature recognition (AFR), and various AFR approaches have been proposed and implemented. The manufacturing features plays important role in both design and manufacturing sectors. 'Design by Features' is concept of defining the product designs through combining the required manufacturing features to realise the product. The antonym process is performed in "Feature Recognition" (shah et al. 1988), in which existing product designs are examined and evaluated, in order to sort-out the manufacturing features and physical manufacturing operations needed to develop the product. The main approaches can be classified into following categories: graph-based approaches, hint-based approaches, hybrid approaches, volumetric decomposition approaches, artificial neural network-based approaches, and currently ontology based semantic approaches (Gao and shah 1988, Vandenbrade and Requicha. 1993, Woo 2002, Marchetta et al. 2010, Sunil et al 2010, and Zhang 2016). One of the most important evaluation criteria for an AFR approach is its capabilities to handling interacting features (Rahmani K, and Arezoo B., 2007), scalability, reusability, and sharing as well as effective mechanism for combining feature recognition with knowledge representation (Zhang et al 2016).

Artificial neural network (ANN)-based feature recognition techniques have been researched because they can eliminate some drawbacks of the conventional feature recognition and they have the ability to tolerate noise in the input data. Sunil et al. (2009), created a hybrid approach i.e., combination of graph based as well as rule based approaches for interacting features recognition from B-Rep CAD models of prismatic components. They combine the structure of the explicit feature graphs and the formulated geometric reasoning rules to recognize the interacting features. The typical ANN architectures most often used in AFR systems are feed forward networks, back propagation (BP), and Hopfield's ANNs. However, the ANN-based approach needs a large number of training samples, and it is difficult to ensure the training process convergence.

Marchetta and Forradellas (2010), presented a hybrid procedural knowledge based approach using Artificial Intelligence (AI) planning which has the potential to handle both feature recognition and process planning under a single framework. As artificial intelligence require more robustness in feature definitions, which become a major limitation to it and is addressed in their work using Hint based approach for handling the interacting features.

Semantic Web based feature recognition techniques has currently received more attention, as it possess the capabilities to address the significant shortcomings of existed feature recognition techniques like scalability, reusability, and sharing. Wang, Q., and Yu, X., (2014), proposed an ontology-based feature recognition framework, in which, features are captured transparently and hierarchically within a formal OWL ontology, and the feature recognition is achieved by applying an efficient backward-chained ontology reasoner. The ontology based feature reasoner has gained more attention of researchers in the feature recognition, as it capable of exhibiting a high level of flexibility, maintainability, and explainability, for both representing and recognizing features.

Zhang, Y., et al. (2016), has proposed a semantic approach for automatic feature recognition of machining features based on semantic query and reasoning. The semantic approach provides an ontology-based concept model for representing the machining faces and machining features. The implicit semantics of machining faces and machining features are defined by a set of explicit Semantics Web Rule Language (SWRL) rules. The automatic feature recognition approach presented in this paper have encapsulated the above mentioned semantic web based feature recognition technologies for effective integration of collaborative cloud networks and to ensure the seamless knowledge transfer among cloud distributed resources.

3. Overview of the proposed architecture and requirements

3.1. Overview of the architecture

The proposed cloud based automatic feature recognition architecture is a new approach to address the most significant issues related knowledge sharing, interoperability and collaboration of distributed resources. The overview of the architecture is outlined in three stages as follows.

- In first stage any cloud user is allowed generate service request or any requirement through user interface of client web portal of cloud computing. The cloud computing technology exhibits multi-tenancy characteristic so that multiple users are enabled to participate at same times and submit multiple requests data of heterogeneous domains. The user data is parsed to ontology owl description logics through common data interface.
- The second stage consist of the key concepts like ontology based automatic feature recognition, in which ontology instances of customer provided design's manufacturing features information are created and then recognized as standard feature entities by using semantic query statements. This features information is stored in knowledge base for further usage in product development phases of manufacturers.
- In the third stage the finalized customer requests are mapped with registered resources of physical resources providers to process the desired service. Optimization/simulation services are provided in cloud platform.

3.2. Technologies requirement under cloud platform

As a central level management system, cloud manufacturing platforms should perform some common functions to support cloud providers and customers to accomplish their transactions. The key functional requirements of cloud manufacturing platforms are the following:

3.2.1. Management of resources

A variety of globally distributed manufacturing resources should be allowed to connect with cloud manufacturing platform based upon their expertise alone. A cloud manufacturing platform should provide real manufacturing resources to the cloud users. These resources can be collaborated, and interoperable under cloud environment with respect to resource capabilities, rather than their size. This nature plays important role for flexible on-demand customization service requests from customers.

3.2.2. Client management

Customers, Resource providers, and application providers, are the different types of clients need to be coordinated through a cloud manufacturing platform. These users are connected to a social network where materials, capital and information are flowing. Cloud platform need to manage well these valuable networks, which will promote deeper collaboration.

3.2.3. Service management

Cloud services have a life cycle of publishing, intelligent matching and composition, runtime management and rating. Similar to the resource pool, all kinds of cloud services aggregate to a service pool. This service catalogue published in network portal, which acts as the basis for operating cloud manufacturing systems.

After facing a request submitted from customer, a cloud platform is responsible for locating service solutions. Once a service request is confirmed at both ends the cloud platform need to configure the manufacturing system by collaborative services of the relevant resources to execute the service request. Typically, this virtual system is established dynamically according to specific requirements.

3.2.4. Knowledge management

The cloud manufacturing depends on powerful support of knowledge and data. Knowledge plays an essential role in enterprise interoperability and collaboration. Multidisciplinary knowledge cannot always be expressed in a structured language. Still a great deal of semi-structured and unstructured knowledge needs to be incorporated into cloud platform.

3.2.5. Technologies integration

Besides the cloud computing, the cloud based manufacturing is the integration of many other web technologies such as semantic web, XML, SQL, cyber technologies, and virtual environment which are employed under one platform. The controlling, coordination and management all the integrated technologies to services execution is major responsibility of cloud manufacturing.

3.2.6. Security and privacy

Security and privacy are the most important and essential functions in the cloud services platform where the huge amount of data that includes classified information may be preserved. Recent works on data security like Subashini and Kavitha (2011) argument in cloud computing, security and privacy is still a critical problem, especially for competitive enterprises need to be taken care.

4. Cloud based architecture for automatic feature recognition in distributed manufacturing environment

This section presents an integrated platform that connects individuals to large manufacturing enterprises by matching the manufacturing requirements with distributed manufacturing resources in the cloud. The proposed architecture is a novel approach to improve the issues related with data sharing and integration, knowledge representation and reusability, and interoperability. The knowledge management makes use of automatic feature recognition for heterogeneous data from various source providers and the service optimization mechanisms is quite adaptable to actual availability information streamed from the shop-floor. Fig. 1 presents the overall architecture of the proposed cloud based AFR framework in Distributed manufacturing environment. The overall process is organised into three main layers:

1. Client requests are verified and parsed by a data parser in client portal of physical resource layer.
2. Ontology based features are identified and transferred to the knowledge base in local server layer.
3. Cloud service layer delivers the optimized services for queries through request–resource matching.

The remainder of this section discusses the three layers, key functional elements of framework in detail.

4.1. Physical resource layer

In cloud based networks the customers become the part of the network originators by admitting their individual requests for the desired services from a list of available resource capacities. Physical resource layer in cloud platform required to establish such a service oriented interaction between clients (customers), application providers, and physical resource providers. The schematic structure of flow of information from end user to local server in physical resource layer is represented in Figure 2.

4.1.1. Clients

Clients are the customers to the cloud platform, those were may be either having the needs to design or manufacture something but lack in capabilities to do so or the others may possess capabilities but participate to trade their facilities to gain the competitive advantage by utilizing cloud platform. Hence the customers can be classified in to two major categories one is service consumers and the other is physical resource providers (PRPs). The clients range is not limited to any small or medium enterprises; they may be any group or individuals that can fulfil engineering needs in support of manufacturing can become a stakeholder in cloud platform. As a part of solution to a significant shortcoming of request customization, this platform enables the consumers to generate the customized service requests, which describe the desired product of specific features, or any computer aided application files are provided to the cloud based user interface layer. The payments by the consumer for service utilization are based on usage time or subscription charges (Adamson et al. 2015). These user requests are transferred to physical resource providers through cloud platform.

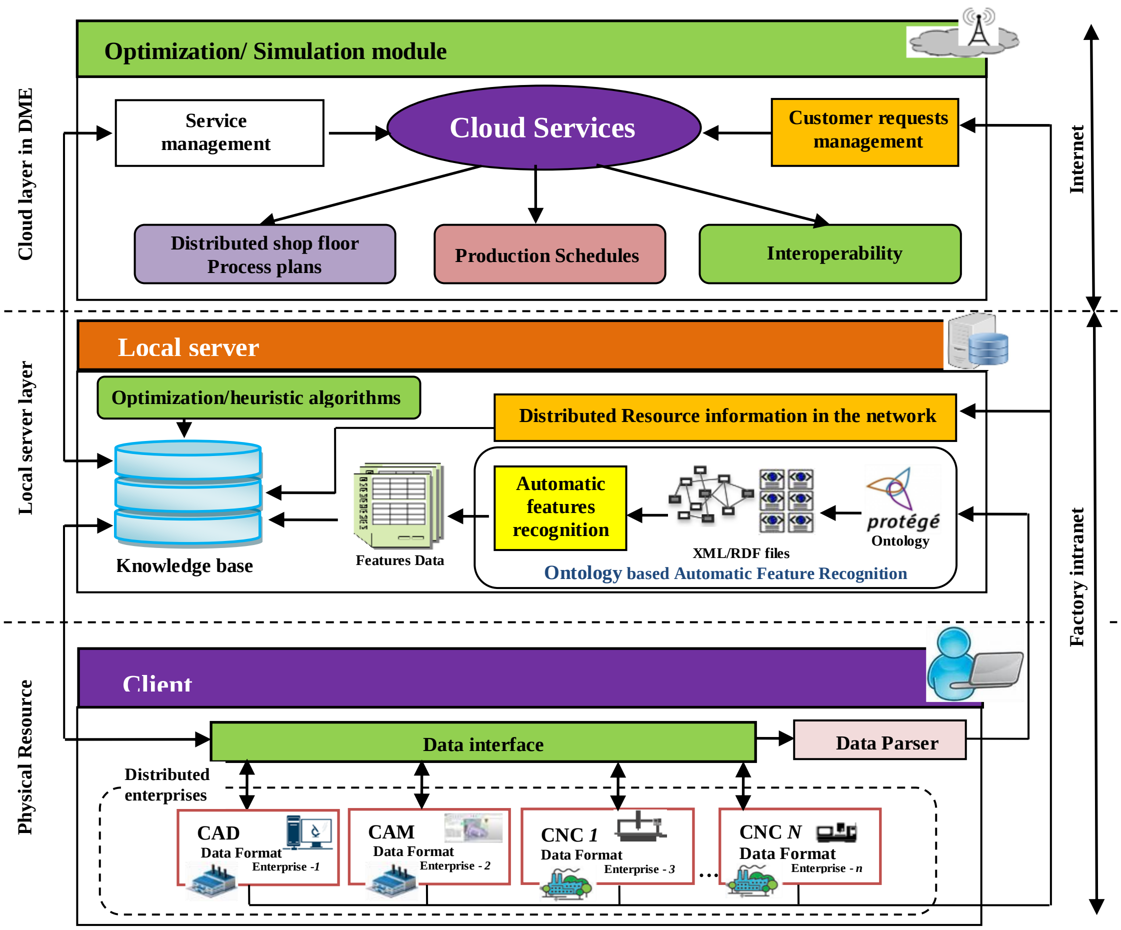

Figure 1. Cloud based architecture for automatic features recognition in Distributed manufacturing environment.

4.1.2. Physical resource providers

Physical resource providers have know-how to efficiently operate their own physical resources while executing customer requests. The PRPs are distributed geographically as individual enterprises, but they are joined in the cloud network as a whole, and are expertise in advanced manufacturing capabilities available in the marketplace, offering users instantaneous access to these capabilities provided through the cloud as a service (Wu et al. 2013). The input to these PRPs is any manufacturing or service requests created by the cloud users, and the output is a finished product or desired optimum services in conformance with user requirements.

4.1.3. Application providers

The application providers are responsible for operation and management of all aspects in the cloud platform and interprets user requirements into knowledge base through common data interface and then publish service orders to PRPs. Application provider delivers functions in more secured way to support both users, PRPs, and platform embedded software technologies. These are responsible for identifying the required resources, coordinating them to match with the required services for accomplishing consumer requests interruption and are liable to make a profitable trade amongst clients and customers.

4.1.4. Common data interface

The common data interface is crucial for data management in physical resource layer, which accepts all types of data formats posted by cloud platform user from different computer aided software packages like CAD, CAM, and CAPP to the cloud platform. Its function is to convert all heterogeneous data in to XML format and in other case XML to user system software supported format to communicate the service result information to the user. Supporting software, XML, HTML and other system query languages are provided to run this common data interface to connect with cloud knowledge base. The data now parsed by the data parser to the automatic feature recognizer through ontology in the next local server layer.

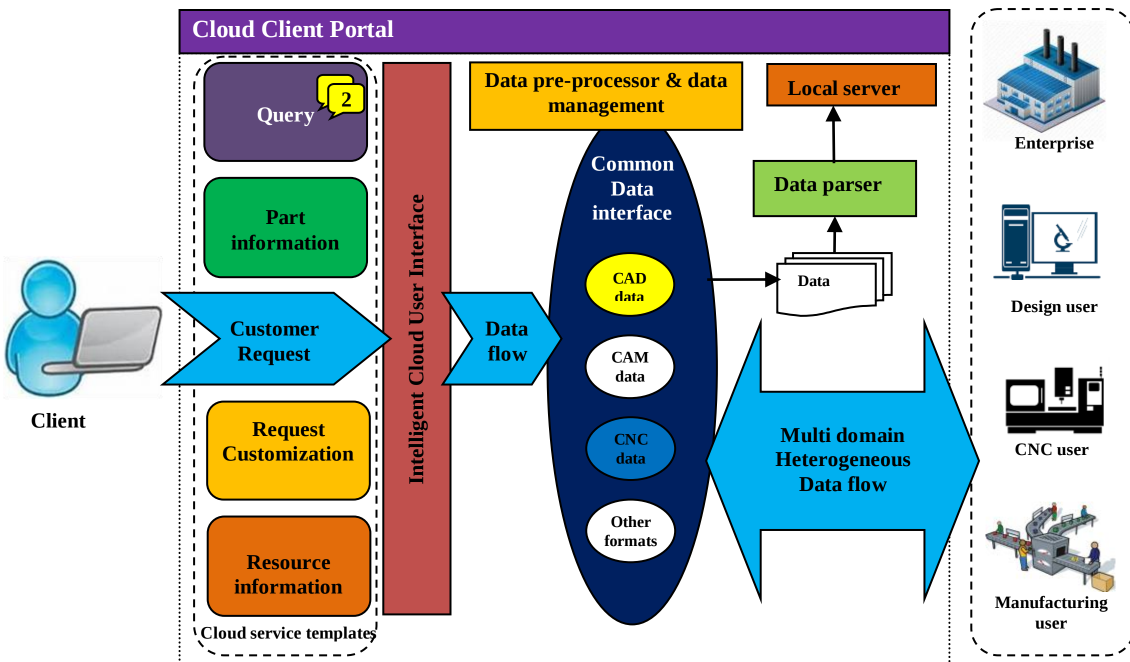

Figure 2. Client interface portal.

4.2. Local server layer

This layer presents the proposed novel approach to mitigate the significant shortcomings of effective seamless data sharing, interpretation and interoperability of distributed manufacturing resources through cloud computing paradigm. Figure 3. Shows the clear structures of the proposed solution presented in this paper as ontology based automatic feature recognition in local server layer.

4.2.1. Ontology based automatic feature recognition

After a service request is parsed by the data parser to local server, the ontology generates '.owl' file instances for corresponding data, and these files are sent input to automatic feature recognizer, from which the feature information of the product is stored in the central knowledge base and becomes part of the integrated domain knowledge.

Web Ontology Language (OWL) is the most widely used ontologies generating language (McGuinness et al. 2004). It provides relations between abstract entities of features with their geometrical annotations which are treated as objects and classes. In this approach the feature knowledge representation is based on ontology description logics, which includes a terminology box (TBox)- contains the concepts, axioms, and relationships among concepts in the machining feature domain, an assertion box (ABox) - contains all the instances in terms of the concepts and object properties, and a semantic web rule base (Horrocks et al. 2004) as it does not provide the reasoning rules such as 'if-then' is defined in the knowledge base using Protégé software. The ABox for feature recognition is designed as a dynamically generated instance box that is integrated in the recognition process. As a result, the ABox becomes a fact base for feature recognition reasoning. These reasoning facts are dynamically generated and ever-changing during the recognition process (Zhang et al. 2016).

The automatic feature recognition (AFR) is the process of extracting machining features and representing them with standard feature formats for the design models given by the cloud users so that a common representation of all machining feature knowledge can be provided across the distributed resources in the cloud network. The advantage of utilizing this approach lies in mitigating the conflicts of user data which is to be compatible with available resources capability data. The AFR technique is well known for its unique features representation procedures to bridge gap between different computer aided software packages used in production sector. Implementation of this AFR technique in cloud platform is the core concept proposed in this paper, which results an efficient, seamless and interoperable data flow channels in cloud networks. As, the features knowledge is key requirement for many manufacturing stages in product development process. The automatic feature recognition process is described in the following steps: (1). Annotating the geometric faces on the contour of design model into a set of instances related to semantic concepts and relationships, these annotated instances provide the reasoning facts for the subsequent feature recognition. (2). Explicitly defined semantic rules are provided in query statements to recognize manufacturing features. (3). The feature recognition is based on a efficient semantic query to the ABox using a backward chained reasoning approach.

The protégé is the ontology editor used to generate annotated ontologies corresponding to feature information of design models. The deployment of 'OpenGL' and 'geometric kernel' technologies provides an interface platform for input the solid models and displaying the recognized machining features in semantic web. In order to define semantic rules to frame query statements to recognition process a semantic web rule language (SWRL) is used (Zhang et al. 2016). The recognized features knowledge is stored in the knowledge base to provide access to the cloud based physical resources providers and share the more reliable and fault less information of products across the global manufacturing networks integrated through cloud.

4.2.2. Knowledge base

The knowledge base is the main data repository for all data used in the cloud as distributed manufacturing system. The purpose of storing all product features, as well as services requests and resource availability data in a database is to share information for the collaboration of distributed resources. The optimal allocation of set of manufacturing resources to consumer manufacturing service requests is a knowledge-intensive activity. There exists a requirement to manufacturer in various stages of product development for repetitive use of existing knowledge (i.e, part designs, assembly instructions, manufacturing processes specifications, and resource capability). To handle these activities a good knowledge-based system is best rather a manual input. To keep data in the SQL database and the knowledge base in sync, a data alignment service is scheduled to run at set intervals.The service request not always suitable to shop floor level manufacturing practices resulting conflicts in reality, hence it not feasible to use a standard knowledge base at all times. A systematic approach to use an automatic feature recognition proposed in this paper can address this issue and update the knowledge base dynamically.

Optimization and simulation algorithms of heuristic and meta-heuristic approaches have been provided to the knowledge base to produce the optimized services desired by the consumer. The services management capabilities are more ensured with these optimization/simulation techniques, which are used provide simulation services or optimized services like production schedules, shop-floor process plans etc., to cloud users.

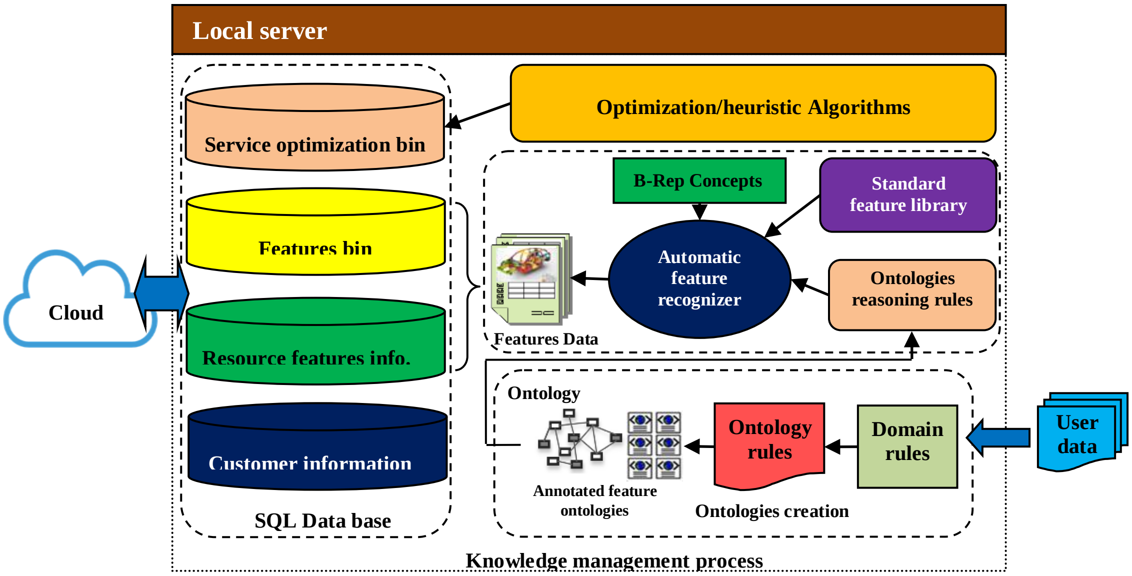

Figure 3. Knowledge management process of features in knowledge base.

4.3. Cloud service layer

This layer is the main area where all computing activities are performed, controlled and coordinated in systematic manner under cloud environment, detailed structure of it is presented in Figure 4. Cloud computing regarded as the sum of three fundamental service models such as Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS) (Buyya et al. 2009 and Xu 2012). Google AppEngine, Windows Azure and Amazon WebServices are the typical examples for the cloud service platforms, where the users can utilise hardware computing resources to customise their own IT infrastructure dynamically, run their applications temporarily and even sell their applications also.

Irrespective of internal structures of the cloud manufacturing platforms, the output brought to customers is ultimately a service. The service application mainly aims to provide service in support of a product development process. Typically, customers can avail services as follows, Design-as-a-Service, Production-as-a-Service, Simulation-as-a-Service, Test-as-a- Service, Maintenance-as-a-Service, Management-as-a-Service, and Integration-as-a-Service. In addition, customers can get collaborative services by composing the above mentioned services, thus support the applications that need across multiple stages of a product life cycle (Ren et al. 2013). The optimization/simulation algorithms provided in this approach as a part of servitisation, can deliver the new services desired by the user including production schedule, and process planning to show in customer interface window.

The deployment models of cloud computing include: public cloud, private cloud, community cloud and hybrid cloud. A public cloud is usually operated by a third-party service provider that offers services to the general public, while private cloud refers to cloud infrastructure, platform and application that serve only a single organisation. A community cloud targets sharing computing resources in a specific society or community where its members have common concerns. A hybrid cloud represents a composition of two or more clouds mentioned above that are connected together but remain relatively independent (Mell and Grance 2009). In this study, depend upon the requirement out of the above mentioned cloud services the appropriate one can be chosen.

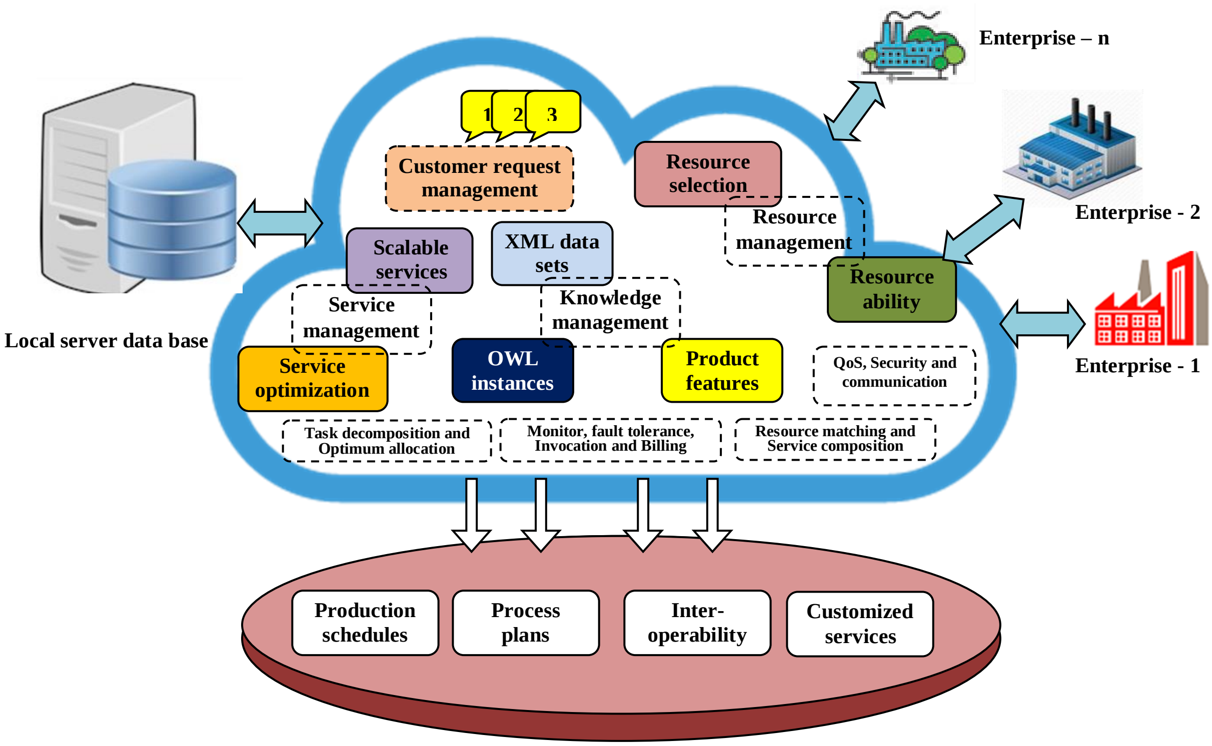

Figure 4. Cloud service layer complete functional scenario.

5. Conclusions and Future work

Recent advances in cloud manufacturing can transform the way enterprises do business. The cloud customers can have access to on-demand services, such as design, production, assembling, testing, simulation, and management. A cloud based automatic feature recognition platform framework has been proposed in this paper for distributed manufacturing environment. To address the issues of heterogeneous knowledge integration, seamless data sharing and interoperability the proposed AFR. In order to make the feature customization easier, the framework separates the feature representation and feature recognition, so that applying changes to feature library will not affect the feature recognition process. Moreover, the deployment of ontology techniques brings a great flexibility for customizing features.

Future research interests may extend network level standardization work on product identification numbers, locations, factories, revisions, should be done. Manufacturing enterprises need to develop standard data to support working in distributed production. Performance analysis needed to ensure key functionalities of cloud platform not to show any practical difference in long run. Further, data security remains an important research area related to use of cloud.

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