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Toward blockchain and fog computing collaborative design and manufacturing platform: Support customer view

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ABSTRACT

Overview of current manufacturing enterprises show that successful global manufacturing enterprise has great collaboration among designer, manufacturer, and customer, which effect on reducing production life cycle and improving customer satisfaction. Recently, several past and ongoing research projects have conducted to enable the collaborative platform to develop effective collaboration with the manufacturing section, design section, and customer views. However, trustable collaboration and how to utilize customer views efficiently is still a challenge. Therefore, this research proposed a blockchain-enabled fog computing-based collaborative design and manufacturing platform to develop triple communication and cooperation among the manufacturing section, design section, and customers in a trustable environment. In the proposed platform, the machine-learning method is used for clustering and categorizing customer-views, and fog computing-based integration between subsystems via blockchain technology is proposed to improve the data integrity and security problem. The proposed platform explained based on key technology, data integrity, key requirement, and illustrative case study. In this respect, we presented the design and manufacturing of bicycles based on customer requests.

1. Introduction

Due to increasing competition in the global marketplace, most manufacturing enterprises continuously improve their productivity and try to reduce the product lifecycle by responding to mass customization [7,30]. These challenges drive manufacturers to adapt and use new advanced technologies and methodologies to achieve a more competitive production model such as cloud computing, cloud design system, cyber-physical system and most recently collaborative cloud design and manufacturing [4,59]. Even though the effect of these technologies has facilitated the exchange of information in different sectors, however manufacturers and designers are still suffering from considering customer views [19].

Nowadays, customer demands for product customization are increased, which pushed manufacturing from mass production to mass customization. Less product life cycle, responsiveness for market change, customer-based design, and fast improvement are the essential characteristics of modern manufacturing enterprises. Therefore, the necessity of a collaborative manufacturing environment has become more sensible [17,32].

Collaborative design and manufacturing platform (CDMP) is a new and novel research area that consists of the subsystems, which are distributed geographically in different locations for the global support market. It improves the design and manufacturing data sharing process, and causes it to reduce the product life cycle [28]. So, it reduces design and manufacturing time [13], and can achieve better communication between design and manufacturing systems [55], which cause to improve product quality [54]. A CDMP needs to have a quick response to diversified demand from the market, which is necessary to consider data integration between the design and the manufacturing sections [21]. Laguionie et al. [28] focused on data integration in CDMP and tried to overcome existing limitations based on STEP standards. Wu et al. [58] attempted to propose a cloud-based design and manufacturing platform by answering this question; "is cloud-based design and manufacturing (CBDM) a new paradigm, or is it just old wine in new bottles?" In this research, the authors considered the design section and manufacturing section on the same platform and explained the critical technology and computer infrastructure of CBDM and defined as a decentralized, networked based on enabling technologies such as cloud computing, service-oriented architecture, social media, and IoT. Most recently, Rauch et al. [46] proposed a collaborative cloud manufacturing platform by considering the design of the business model

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and solved integration problems by using the cyber-physical system in the manufacturing section. However, existing platforms are suffering from processing and formating of customer views, which requires effective methods for categorizing, and classifying of customer views. Therefore, it can be found that several research gaps still exist in CDMP as follow:

Firstly, product designers and manufacturers need to take into account the views of customers [26]. Still, existing collaborative systems lack an effective method for the use of customer views, which reduced mass customization [65]. Secondly, the customization of the product contains different sections, such as manufacturing and design. Therefore, the response to these views needs to executed by various sections. Only the manufacturing sector can provide a professional solution to production problems. So how to categorize customer feedback based on different sectors is a challenge. [56]. Thirdly, most of the CDMP is developed based on a public cloud environment, which is already suffering from security issues, and hysteresis in data transmission [2,3,1,22] and data integrity [15].

Therefore, the primary objective of this paper is to answer the following questions: How can customer views support CDMP? Besides, how to cluster and categorize customer views for achieving useful knowledge? And how can we improve the security of the CDMP platform? We answer these questions by design and development blockchain-enabled fog computing-based collaborative design and manufacturing platform, which can achieve communication and cooperation among the manufacturing section, design section, and customers. The platform utilizes customer feedback and analyzes these opinions to make useful knowledge and promote the manufacturing and the design process based on customer demands continually. This platform used a semantic analysis paradigm to analyze customers` views in the cloud environment, and it utilized a kind of machine learning algorithm such as a support vector machine (SVM). Also, the platform used fog computing as the structural support of the proposed system. For improving data security, we proposed blockchain-based fog computing communication. Fog computing extends computing power and data analytics applications to the "edge" of the network, enabling users to analyze and manage data locally, gaining immediate insight through connectivity and relieve the pressure of centralized computing in cloud computing. Briefly, the proposed platform promotes the triple connection and data integration in the CDMP and makes customer views formulated to use for design and manufacturing sections.

The rest of paper is organized as follow; Section 2 provides a literature review about collaborative design and manufacturing platform, customer views processes and formulation, fog computing, and blockchain technology. Section 3 proposed the platform by considering methodology. Section 4 focused on key technical processes on the proposed platform. Section 5 explained the vital features and requirements of the proposed platform. Section 6 explained the proposed platform based on an illustrative case study. Section 8 and 7 provide the discussion and conclusion, including implication, limitation, and future work.

2. Literature review

In this section, the concept of CDMP is explained from both technical and theoretical aspects, then the customer views are defined, and suitable methods based on the literature review explained. Then cloud computing and fog computing are determined based on the current research works. Finally, blockchain technology is explained by highlighting the possibility of improving the security of the CDMP platform.

2.1. Collaborative design and manufacturing platform

Research on the CDMP is started when manufacturing enterprises shift to the distributed manufacturing paradigm, for covering high customer demand and reducing product lifecycle [67]. Data integration is a crucial and necessary part of this platform to have data synchronization in the CDMP, which distributed geographically [24]. The CDMP aims to improve product quality, shorten lead-time, increase product competitiveness, and satisfy customers' demand. Nowadays, many researchers have focused on the collaborative development platform [31]. Wangwei Chu et al. [14] proposed a collaborative manufacturing framework for aircraft structural parts, which utilized multi-agent technology by considering machine level and simulation level. Dazhong Wu et al. [58] presented a cloud-based design and manufacturing platform. The authors provided detailed information about cloud-based design and cloud-based manufacturing and explained CBDM based on cloud computing, IoT, and service-oriented architecture. This platform considered a new paradigm that anticipated to drive digital manufacturing and design innovation and introduced new networking infrastructure. Yajun Lu et al. [34] outlined an IoT-based collaborative framework. This framework utilized cloud-computing technology and used engineering Enterprise Modeling Language (eEML) as a descriptive method. Prashant Tuli et al. [51] proposed a collaborative system applying lean principles between an automotive component supplier and the original equipment manufacturer. This new method helps improve design quality, team motivation, knowledge creation, and better adherence to schedule. Omid Fatahi Valilai et al. [52] developed an integrated and collaborative manufacturing platform named LAYMOD. This platform was applied in various cooperative and integrated CAx systems. The improved method was called XMLAYMOD, which supported distributed manufacturing collaboration and data integration based on the STEP standard. Alireza Mokhtar et al. [40] developed a universal manufacturing platform (UMP) to achieve interoperable among design, manufacture, and other activities in the product lifecycle. The platform utilized the STEP standard for the exchange of product data between different departments. All current research works are concentrated more on the innovation of the technologies and data integration between the manufacturing and design sections, and they have not integrated customer views as an effective parameter to the platform. It is evident that considering customer views play a crucial role in customer satisfaction, which improves the income of enterprises by making loyal customers and the ability to shift from mass production to mass customization [60]. In addditon, the existing platforms are not secur and have trust problems, which is highly important for the manufacturing industry.

For a better understanding of the existing literature review, Table 1 provided an identical evaluation of the most well known collaborative design and manufacturing platforms. This table includes specific characteristics of CDMP, such as trustable collaboration, collaboration efficiency, response time, scalability, data security, and data integrity.

2.2. Customer view

Usually, customer view and feedback are defined as comments that presented in natural language text. Therefore, we use natural language to describe a request. It's necessary to adopt text categorization technology as a tool to achieve the classification of customer views in the digital environment. The text categorization (TC) is used as a computer algorithm to automatically mark the text set according to a particular classification system or standard [16]. The research about TC has a history of more than 50 years. Most of the researchers utilized the machine-learning method to solve TC problems. Alexander Genkin et al. [20] presented a simple Bayesian logistic regression approach. Bo Tang et al. [50] showed a Bayesian classification approach for automatic TC using class-specific features. Kijung Park and Gul Kremer [43] applied text mining-based categorization and user perspective analysis of environmental sustainability indicators for manufacturing and service system. V. K. Manupati et al. [38] established a support vector machine (SVM) based classification algorithm for classifying the text data into two broad categories of manufacturing and non-manufacturing suppliers. M. Rushdi Saleh et al. [48] applied SVM for classifying different

Table 1
Characteristics of existing platforms.

Research	Trustable collaboration	Collaboration efficiency	Response time	Scalability	Data security	Data integrity
[14]	O	O	O	O	O	O
[58]	O	P	O	P	O	O
[34]	O	O	P	P	P	O
[51]	O	P	O	O	O	O
[52]	O	O	O	P	P	P
[40]	O	O	P	O	O	O
[12]	O	P	P	O	O	O
[63]	O	P	O	O	O	O
[5]	O	P	P	P	P	O
[27]	O	P	P	O	P	O

customer comments on the product in various blogs and forums. They applied SVM for the testing dataset in different domains, and the result showed that the use of SVM could be helpful for accurately reflecting the general customer view of the product. Huosong Xia et al. [61] proposed sentiment analysis to the comments on the internet-based SVM. They analyzed the influence of different stopword removal methods on the result of text classification and implemented the classification with the technology of SVM. According to the researchers above, we can find that text classification, especially SVM, has been adopted to analyze customer views, and the SVM method is helpful and can have a superior performance in classification efficiency and accuracy. A literature review by authors illustrated that machine learning is a suitable tool for categorization and classification of customer views on the CDMP.

2.3. Fog computing

Fog computing was proposed in 2011, and it extends the cloud computing technology to the edge of the network [10]. Proper implementation of fog computing can meet the requirements of mobility support and geo-distribution [9]. Fog computing has broad applications in a distributed system because of its more massive computing and distribution compared with cloud computing [25]. Deze Zeng et al. [66] proposed a fog computing platform as a solution to support and strengthen the traditional embedded system. They considered a fog computing assisted software-defined embedded system. This system can reduce task completion time. Roby Lynn et al. [36] applied IoT and fog computing to achieve embedded data acquisition and analysis devices at the shop floor level at a low cost. MTConnect was used to manage production data during manufacturing. Peter O'Donovan et al. [42] presented a cyber-physical system based on fog computing, through which can embed a machining learning model into the industrial operations. This system solved the problems of decentralization, security, privacy, and reliability. Rui-Yang Chen [11] proposed a food traceability collaborative platform based on fog computing. This platform improved collaborative traceability efficiency and explored the distributive stream mechanism. Therefore, fog cloud computing can be a kind of suitable infrastructure for deploying collaborative design and manufacturing platforms, which are supported by distributed systems and integrated customer views data with other sections.

2.4. Blockchain technology

blockchain technology is a kind of concept based on a distributed ledger. The essence of blockchain is a distributed database [37]. There are several characteristics of blockchain: (1) multiple copies; (2) reliable records; (3) non-tamperable; (4) decentralization management. Based on these characteristics, the main advantages of the blockchain is to establish a secure and trustworthy data-sharing mechanism [23]. Nowadays, the application on blockchain has not been limited to Bitcoin. As for the healthcare data sharing field, Yue et al. [64] proposed a decentralized application architecture. Compared with traditional centralized healthcare data management systems, the proposed system helps patients own, control, and share their data securely without the infringement of privacy. Sun et al. [49] concentrated on the blockchain application in a smart city. They proposed a conceptual framework, which described from human, technology, and organization dimensions, and made the smart city from sharing economy perspective. Ali V Barenji et al. ([53]; Vatankhah et al., 2020) proposed a blockchain-based cyber-physical system for ubiquitous manufacturing and industrial 4.0. In the blockchain, a smart contract is a critical component to establish a trust mechanism. McCorry et al. [39] proposed a decentralized and self-tallying internet voting protocol based on blockchain, which was written as a smart contract in Ethereum platform. The application of smart contracts ensures that voting members strictly enforce voting rules. Li, Zhi, et al. [31] proposed Automl approach for open and automated customer service. The application is based on the smart contract of the Ethereum blockchain. Therefore, it can be seen that the smart contract in the blockchain can be utilized as the underlying technology of the sharing platform. The utilization of the blockchain provides a secure and trustable data sharing environment [29].

Briefly, our proposed platform utilized SVM, fog computing, and blockchain technology. SVM is used to classify customer views, fog computing is utilized to improve efficiency and reduce latency, and blockchain technology provided trustable and secure data sharing in the platform. With the use of these critical technologies, the proposed platform can cover the existing problems, such as supporting customer views, scalability, and security.

3. Methodology

3.1. The conceptual framework of the platform

According to existing definitions for CDMP [46,58,67], our proposed platform aiming to improve collaboration between the manufacturing and design sections by considering customer views in the trust and security environment. In this platform, the tripartite information is encapsulated to different fog computing nodes, and each of them uses blockchain technology for peer to peer communication. The conceptual framework is shown in Fig. 1. The platform consists of four parts, namely customer feedback, manufacturing system, design system, and big data repository and analysis (BDRA). Each section is described as follow:

1. The customer feedback part is represented customer feedback about products, which is on the E-commerce website; there is raw text and without any process which is need clustering and categorizing method for achieving the suitable design and manufacturing knowledge. These texts are sent to the big data repository and analysis section for categorization and clustering. Social media technology is the main component of this part and plays a vital role in this part for creating a suitable connection between customers

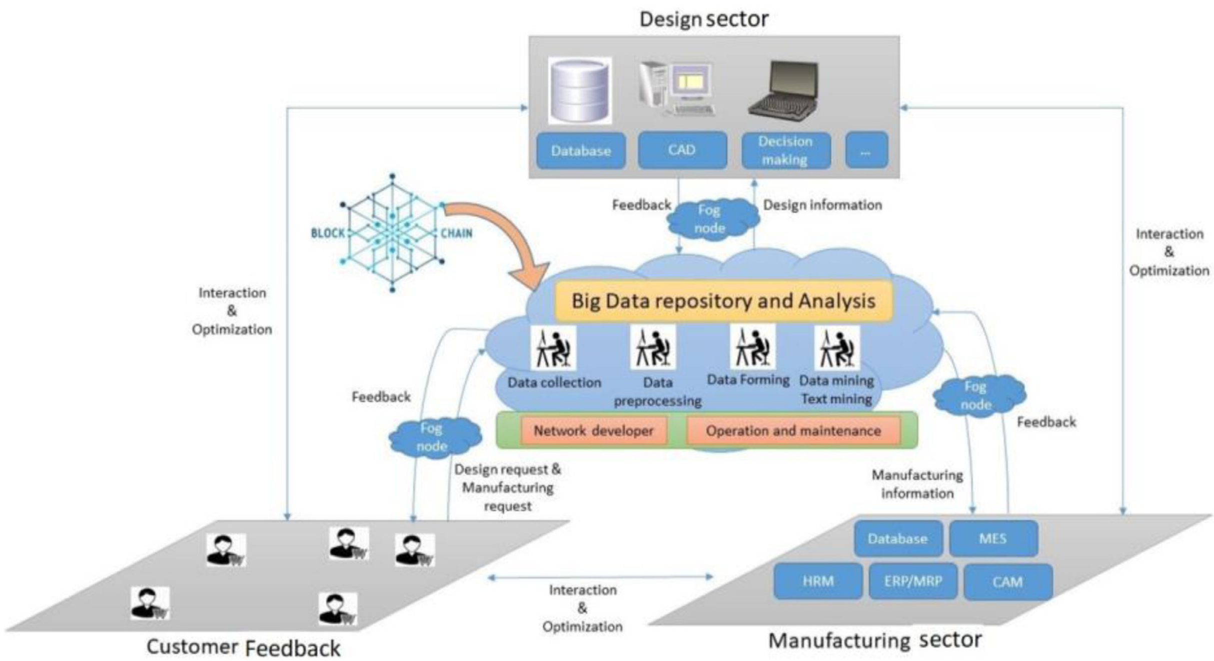

Fig. 1. Conceptual framework of the platform.

and the proposed platform.

2. The manufacturing part is mainly responsible for the management and execution of physical resources for providing manufacturing as a service, which is geographically distributed. It consists of manufacturing execution system (MES), human resource management (HRM), enterprise resource planning (ERP), and material requirement planning (MRP), which control and monitor manufacturing resources regarding product production. Integration between software level and hardware level in this part was developed and implemented [6,8]. In the proposed platform manufacturing layer directly communicated with the BDRA part for storing and processing big data via fog computing technology.
3. The design part is mainly responsible for the design process, namely conceptual design, detail design, and verification part. The design part uses processed knowledge, which provided by BDRA via blockchain network to improve the product and achieve customer-based design. Therefore, customer views information and communication information with the manufacturing system has been stored in the BDRA, and the design part accesses for this information for redesign product. All communications between each section are provided via the blockchain layer, which is peer to peer and secure network.
4. The BDRA is the main section of the proposed platform, which is supporting big data of the system and uses machine-learning methods for text classification, clustering, and processing of customer views, and developing customer-based knowledge for the manufacturing and design part. Therefore, all three elements are communicated with BDRA via blockchain technology, which used fog computing (node) for data transferring, analysis, and storing. In the next section, this part will be explained entirely by considering the machine learning method.

To achieve real-time data integration and improve data integrity on the CDMP and fully support of distributed system on the trust environment, the developed platform uses fog nodes and blockchain-based communication between each section. Fog nodes consist of weaker performance and more decentralized types of functional servers. These servers can provide different computing, storage, and networking capabilities and support the execution of service applications, which improve the data integrity of the entire system. They can also act as miner nodes for the blockchain network. Therefore, the fog nodes significantly reduce the amount of data send to the cloud center, which is sufficient for reducing the latency of the network because of local computing power, and also, these nodes are helpful for verification of new members and existing members on the blockchain. The main advantage of a fog based system supports a distributed system and acts as miner nodes that highly desirable in our proposed platform.

3.2. Architecture of the platform

Figure 2 shows the layer-based architecture of the proposed platform. It contains five layers: the raw data layer, fog computing layer, big data analysis layer, knowledge layer, and the application layer, which are connected via the blockchain network. Each layer is introduced as follows:

(1) Raw data layer: It includes customer reviews or a specific request by the customer, which send to the platform. The raw data are saved in a cloud environment, which is unprocessed or not simplified data and cannot be machine-readable. In this layer, three types of data exist, manufacturing data, which is responsible for the manufacturing process, and illustrated the capability of the manufacturing system, design data which is used for the design process, and customer review comments data. All of the data are based on the text data format. All of them can be categorized as big data and can use Fog node and blockchain technology to transfer to the cloud environment.
(2) Fog computing layer: The Fog computing layer consists of several fog-computing nodes, which responsible for developing transactions between different sections and the cloud environment. As we mention, today's manufacturing and design departments are distributed geographically, so Fog-based communication via blockchain improves the security and scalability of the platform. Each fog node receives data from the subsystem and encapsulates this data into the cloud environment. Meanwhile, each fog nodes acts as a miner on the blockchain.
(3) Data layer: This layer is divided into two main parts. The first part contains the storage of big data in the three different categories.

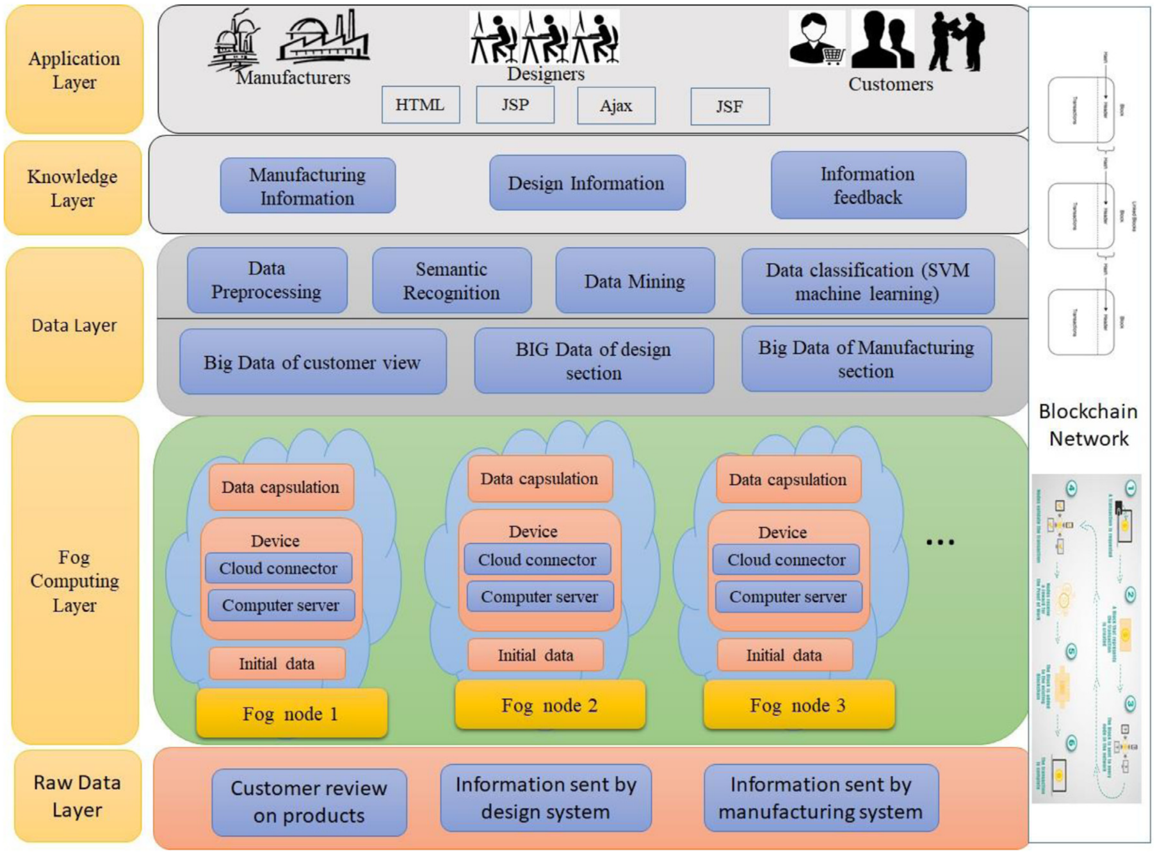

Fig. 2. Architecture of the platform.

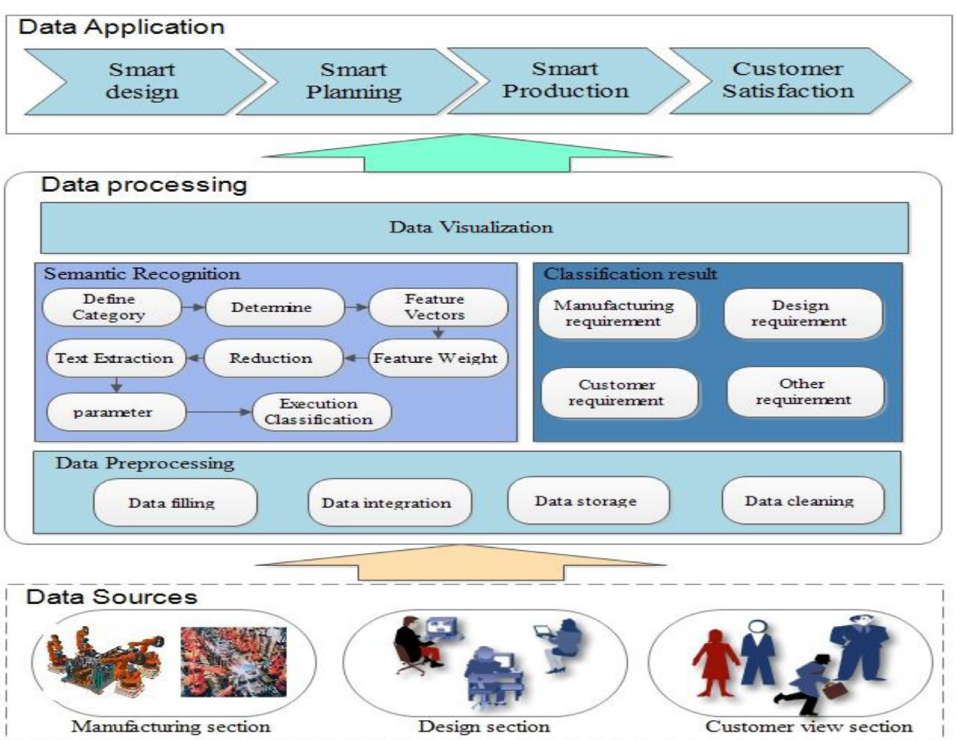

Fig. 3. Machine learning process for customer views.

These data are transferred from the fog node to the cloud environment and stored at the cloud database for process and classification. Big data include many structured and unstructured data, such as product data, service data, supply chain, equipment data, design data, simulation data, and culture data, and so on. The next part of the data layer is the data algorithm and, which is responsible for clustering, classification, sorting, and process of the big data. In this context, customer feedback or comment transfer to useful knowledge by the proposed machine learning algorithm. Figure 3 shows the machine learning processes. This figure is developed based on the customer views comments, shows that how comments cluster, and categorized on this layer. For this purpose, semantic recognition is used. Semantic recognition aims to automatically segment a sentence, organize the structure of the sentence, and understand the meaning of the sentence. The semantic recognition usually includes sentence segmentation, part of speech tagging (POS tagging), and syntax parsing. Semantic recognition helps the platform understand the meaning of natural language.

(4) Knowledge layer: It responsible for formating data and developing knowledge-based on customer views comments. In this layer, knowledge is categorized into three parts, namely design knowledge, manufacturing knowledge, and feedback to a customer. For example, the customer sends comments and asking for a specific product; this information transfer to the cloud environment by fog node based on blockchain communication. After receiving this raw data, the data is categorized and formulated via the proposed ML method in the data layer and send it to the knowledge layer. This layer acquires processed data and categorizes and develops knowledge for each section. Then it forwards the corresponding data to each section as a service. Therefore, new knowledge based on customer views is developed and provided for a suitable section.

(5) Application layer: It is responsible for providing different specific interfaces and related end-interaction tools. This layer uses web-based applications and provides an interface for customer, manufacturing, and design sections. The manufacturers, designers, and customers can receive and read this information through the interfaces. This information is visualized on a developed front-end interface. Each user of the platform has the authority to attain corresponding details. For example, the manufacturing information transport to manufactures interfaces and be read by the manufactures in the front-end interface.

(6) Blockchain network: Blockchain network is responsible for establishing a connection among different sections. With the utilization of blockchainin, different parts can set reliable data sharing rules and construct a secure trust mechanism based on the smart contract. The smart contract aims to automate the process of data sharing. A smart contract involves multiple users of the blockchain to work out a protocol. In this case, it is drawn by the design section, manufacturing section, and customer. The operation mechanism of a smart contract is shown in Fig. 4. It generally has two attributes: value and state. The smart contracts are submitted by multiple parties through mutual agreement and signed by each user. After being transmitted by the P2P network and verified by nodes, they stored in a specific block of the blockchain. The detailed operation of the smart contract is shown in Fig. 5. Firstly, the BDRA send a request to customer for attaining raw data. The content of the smart contract includes a rule of data sharing and the triggering condition for the sharing process. In the code, hypothetical statements are used to pre-define the corresponding trigger scenarios and response rules for contract terms. There is also a hash in the smart contract, which is marked as the data source address. The smart contract is stored in the blockchain and confirmed by the customer. Once the confirmation is finished, and the trigger conditions are accepted, the smart contract is executed, and the raw data of the customer is transferred to BDRA. The two sides of the share build a trust mechanism through smart contracts. After data processed and analyzed in the BDRA, the data is shared with the manufacturing section and the design section. In the manufacturing data sharing phase, the manufacturing section sends the request of the manufacturing data, and design data then initializes the smart contract. The smart contract includes information of both parties, conditions for execution of the transaction, and the data types. This smart contract is stored in the blockchain and confirmed by the BDRA. If the confirmation of the smart contract is finished, then executed, and the BDRA provides the data to the manufacturing section. In the design data sharing phase, similarly, the design section requests design data and manufacturing data. After the initialization and confirmation of the smart contract, the corresponding data is sent to the design section. All the smart contracts are written by Solidity, a common language for developing the blockchain. Figure 6 shows an example process of smart contract upload and confirmation. In Solidity, smart contracts are similar to a class in an object-oriented programming language. Each contract can contain state variable, function, function modifier, event, structure and enumeration types, and contracts can inherit from other contracts. State variables are values that are permanently stored in contract storage. A function is an executable unit of code in a contract. Function calls can occur inside or outside the contract, and functions have different degrees of visibility to other contracts. This figure shows features and how the smart contract uploads to the blockchain and the signature about the smart contract. The function modifier can use to improve function semantics in a declarative way. The events are interfaces that can easily call the Ethereum virtual machine log function. The structure is a custom type that can group several variables. Enumeration types can be used to create custom types made up of a certain number of constant values. With the utilization of the smart contract, all the sharing process is protected, because the sharing process is executed based on the smart contract and monitored by the nodes in the Blockchain. The trust between users is achieved through smart contracts.

4. Key technical process

4.1. Text categorization using SVM

In the proposed architecture, SVM is utilized for classifying each sentence into two classifications. One classification belongs to manufacturing data, and the other belongs to design data. SVM is a generalized linear classifier that classifies data in a supervised learning manner. As a Bi-classification model, its purpose of finding a hyperplane to segment the sample. The principle of segmentation is to maximize the interval and transform into a convex quadratic programming problem. It has been recognized as one of the successful classification algorithms for many applications, including text classification (Z. [57]).

Consider there are m samples that represent m sentences and belongs to two different classes:

$$\{(\boldsymbol{x}_i, y_i)\}_{i=1}^{m}, \quad y_i \in \{-1, +1\} \tag{1}$$

where $\boldsymbol{x}_i$ is an n-dimension column vector, n is dependent on the number of feature words in the general dictionary. For example, there are 50 feature words in the general dictionary; therefore, n equals to 50. y_i is the class label that each vector belongs.

SVM utilizes a hyperplane to classify the samples into two classes

$$\boldsymbol{w}^T\boldsymbol{x} + b = 0 \tag{2}$$

where $\boldsymbol{w} = (w_1; w_2; \ldots; w_n)$ represents the average vector. It is a column vector that determines the direction of the hyperplane. b is the displacement term, which defines the distance between the hyperplane and the origin. x represents the input vector. The distance from any point x to the hyperplane in the sample space can be written as

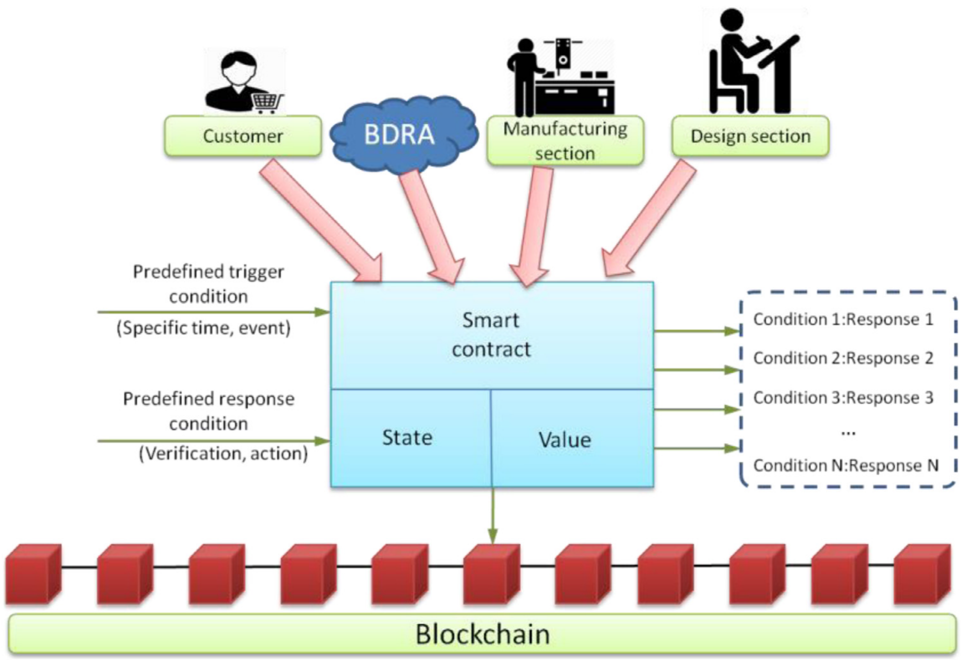

Fig. 4. Operation mechanism of the smart contract.

$$\gamma = \frac{|\boldsymbol{w}^T\boldsymbol{x} + b|}{\|\boldsymbol{w}\|} \tag{3}$$

Assuming the hyperplane can correctly classify the training samples, that is, for $(\boldsymbol{x}_i, y_i) \in D$, if $y_i = +1$, then $\boldsymbol{w}^T x + b > 0$, and if $y_i = -1$, then $\boldsymbol{w}^T x + b < 0$. Let

$$\begin{cases} \boldsymbol{w}^T\boldsymbol{x}_i + b \geq +1, y_i = +1 \\ \boldsymbol{w}^T\boldsymbol{x}_i + b \leq -1, y_i = -1 \end{cases} \tag{4}$$

The training sample points closest to the hyperplane make the equal sign of formula (4) hold. They are called "support vectors". The sum of the distances of two heterogeneous support vectors to the hyperplane is

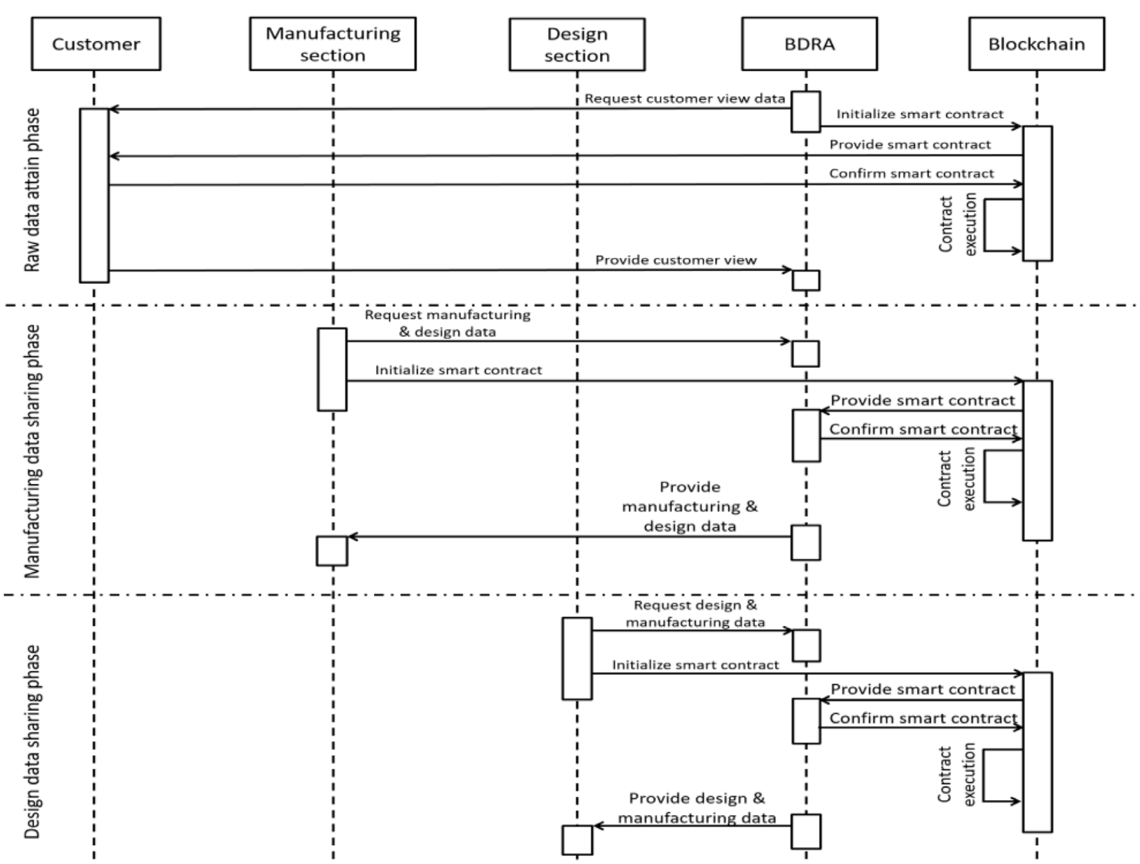

Fig. 5. Execution process of smart contract.

```
function agreementUpload(
    uint32 AgreementNum,
    address section_1,
    address section_2,
    uint money,
    uint expiry
    ) returns(bool) {

    require(msg.sender == section_1);
    require(section_1 != section_2);
    require(expiry > block.timestamp);

    purchaseAgreement storage _tempAgreement;
    uint initLength_1 = agreementQueue[section_1].length;

    _tempAgreement.AgreementNum = AgreementNum;
    _tempAgreement.section_1 = section_1;
    _tempAgreement.section_2 = section_2;
    _tempAgreement.money = money;
    _tempAgreement.expiry = expiry;
    agreementQueue[section_1].push(_tempAgreement);
    if(agreementQueue[section_1].length > initLength_1){
        return true;
    }else{
        return false;
    }
}
function sign(address addr, uint32 AgreementNum) public returns(bool) {
    uint index = getAgreementByNum(addr, AgreementNum);
    address section_1 = addr;
    address section_2 = agreementQueue[addr][index].section_2;
    address[] sign = agreementQueue[addr][index].sign;
    require(msg.sender == addr || msg.sender == section_2);
    for(uint i= 0; i < sign.length; i++){
        if(sign[i] == msg.sender){
            return false;
        }
    }
    sign.push(msg.sender);
    return true;
}
```

Fig. 6. Smart contract upload and signature confirmation.

$$\gamma = \frac{2}{\|\boldsymbol{w}\|} \tag{5}$$

which is called “margin”. SVM aims to find a divided hyperplane with a "maximum margin", that is, to find the parameters $\boldsymbol{w}$ and b that satisfy the constraints in formula 4 to maximize γ.

$$\max_{w,b} \frac{2}{\|\boldsymbol{w}\|} \tag{6}$$

s.t. $y_i(\boldsymbol{w}^T\boldsymbol{x}_i + b) \geq 1$

The optimism objective can be equivalent to

$$\min_{w,b} \frac{1}{2}\|\boldsymbol{w}\|^2 \tag{7}$$

s.t. $y_i(\boldsymbol{w}^T\boldsymbol{x}_i + b) \geq 1$

(7) is a convex quadratic programming problem so that the Lagrange multipliers can solve its approach by transferring to the dual problem.

Specifically, Add Lagrange multiplier $\alpha_i \geq 0$ to each constraint of Eq. (7), then the Lagrangian function of the problem can be written as

$$L(\boldsymbol{w}, b, \boldsymbol{\alpha}) = \frac{1}{2}\|\boldsymbol{w}\|^2 + \sum_{i=1}^{m} \alpha_i(1 - y_i(\boldsymbol{w}^T\boldsymbol{x}_i + b)) \tag{8}$$

where $\boldsymbol{\alpha} = (\alpha_1; \alpha_2; ...; \alpha_m)$. Let $L(\boldsymbol{w}, b, \boldsymbol{\alpha})$ make partial derivatives of $\boldsymbol{w}$ and b to 0 and get

$$\boldsymbol{w} = \sum_{i=1}^{m} \alpha_i y_i \boldsymbol{x}_i \tag{9}$$

$$0 = \sum_{i=1}^{m} \alpha_i y_i \tag{10}$$

By substituting Eq. (9) into Eq. (8) and considering the constraints of (10), the dual problem can be defined as

$$\max_{\alpha} \sum_{i=1}^{m} \alpha_i - \frac{1}{2}\sum_{i=1}^{m}\sum_{j=1}^{m} \alpha_i\alpha_j y_i y_j \boldsymbol{x}_i^T \boldsymbol{x}_j \tag{11}$$

s.t. $\alpha_i \geq 0$

$$\sum_{i=1}^{m} \alpha_i y_i = 0$$

By solving $\boldsymbol{\alpha}$, the model function can be derived as

$$f(\boldsymbol{x}) = \sum_{i=1}^{m} \alpha_i y_i \boldsymbol{x}_i^T \boldsymbol{x} + b \tag{12}$$

By inputting the test sample $\boldsymbol{x_t}$, the output can be derived as

$$f(\boldsymbol{x_t}) = sgn\left(\sum_{i=1}^{m} (\alpha_i y_i x_i^T \boldsymbol{x_t} + b)\right) \tag{13}$$

In summary, the text categorization utilizing SVM has five steps:

(1) Take each sentence of the text of the customer views as an input sample.
(2) Use the word segmentation tool to extract all the sample words like a dictionary.
(3) In order to avoid the curse of dimensionality [18], feature selection is executed to select some representative words from the dictionary to construct a feature vector without affecting the classification

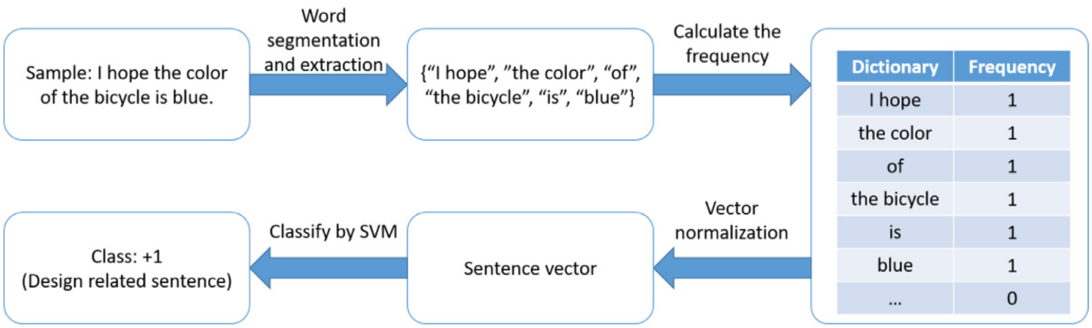

Fig. 7. Example of how SVM classify a sentence.

effect.

(4) Transfer the sentence to a vector. According to the feature vector that has been generated, if the word in the feature vector appears, then it is filled in the corresponding position at the sentence vector.
(5) Normalize the generated vector and use it as input to the SVM model. Set the label of manufacturing-related sentence text as +1, and the design-related sentence text as −1.

Fig. 7 shows a detailed example of how the SVM classifies a sentence. The sample is extracted by sentence segmentation from a customer review. Natural Language Toolkit (NLTK), a suite of open source program modules, is utilized to achieve this function [33]. The sample is segmented firstly to extract all the words. In order to obtain some phrases, the N-gram method is utilized so that some common phrases can be extracted (Brown, Desouza, Mercer, Pietra, & Lai, 2016). In this sample, "I hope," "the color" "of" "the bicycle" "is" and "blue" are extracted. Secondly, according to the dictionary, if a word appears in the dictionary, fill in the word frequency of the expression at the corresponding position. The dictionary is a feature set. It consists of some representative words about design and manufacturing, and so on. Besides, the feature weight is determined according to the word frequency. At last, the sentence vector is generated by vector normalization and set as an input of SVM. The classified show that this sentence is design-related. All in all, SVM can efficiently and automatically categorize customer reviews to determine which are related to manufacturing and which are related to design.

4.2. Communication and data integration

One of the main goals of this research is to develop trustable triple commutation between three main sections in the production life cycle. For achieving this goal, the first challenge is to cluster and categorize data to develop knowledge that is useful for manufacturing and design sections. As mention in Section 4.1, this challenge is overcome by SVM. After classifying and formating is transferred to design and to manufacture knowledge. For improving triple communication, each section used fog node and blockchain technology for connecting to a cloud environment [35]. Fog node forms the network edge layer between the terminal departments and the cloud data center. They are usually small servers or routers with memory. Data that does not need to be stored in the cloud directly are processed and stored in the fog nodes. Therefore, the existence of fog nodes can significantly reduce the computing and storage pressure, improve efficiency, increase transmission rate, and reduce latency. In addition, Fog node transfers big data to the cloud for storage purposes, and this data is distributed via blockchain technology, and the security of these data is guaranteed Blockchain. After storing data on the cloud, each section uses a specific data algorithm and structure for processing of achieving synchronized data. After forming of data, encapsulation is done on data then communication between these sections occur on data fusion. So, when any section requests for services or knowledge, the useful data is supported by data fusion in the cloud environment. Real-time data connection and data integration in the cloud environment is shown in Fig. 8.

5. Key features and requirements

The key features of the proposed platform are compared with existing CDMP and summarized in Table 2.

According to Table 2, it is clear that the proposed platform need some specific requirements from these features, the provisions of the proposed platform defined as follow;

The first requirement of the proposed architecture is connectivity, the end-users or customers use existing technology based on the network for connecting to platform, in this respect, customers, manufacturers, and designers use blockchain decentralized application (Dapp) for connecting the cloud environment, and each of them acts as Fog node in the platform. The second requirement is the cloud environment; in this research, it is used for storing and processing big data. The third requirement is broadcast developed knowledge, which is covered by the data mining approach. The fourth requirement is real time data communication. The cloud environment provides open-source software and storage for this requirement and uses appropriate data algorithms for the cleaning and processing of data. The fifth requirement is the interaction between the design and manufacturing section. In this respect, data fusion-based integration is used for the integrity of the data in the cloud environment. The sixth requirement is providing trustable collaboration between different sections. The proposed platform uses membership verification and smart contract technology on the blockchain for this purpose.

6. Illustrative example

In this section, we select a bicycle company as a case study to illustrate the main objective of the proposed platform. This example helps to clarify and demonstrates the potential values of the proposed architecture. Specifically, the example shows how the prototype of the product obtains based on three-design stages, namely conceptual design, detailed design, simulation by considering customer views and communication with the manufacturing section. It also shows how the platform can support customer views throughout the entire process. Fig. 9 illustrates the scenario by considering customer views in the design section and the manufacturing for obtaining new products. As shown in this figure, the design process and manufacturing of a bicycle are systematic. The first step is a conceptual design that uses a platform as a service (PaaS), software as a service (SaaS), and Data as a service (DaaS). DaaS contains customer views, knowledge, customer feedback, manufacturing data, and cultural data. All the data are provided for the designer via a developed platform based on accepted format, and then the designer can use this knowledge in the first step of the design process. The second step is a detailed design that used SaaS, such as CAD software, DaaS, and Big data storage and analysis as a service (BaaS). In this step, DaaS is responsible for providing customer and

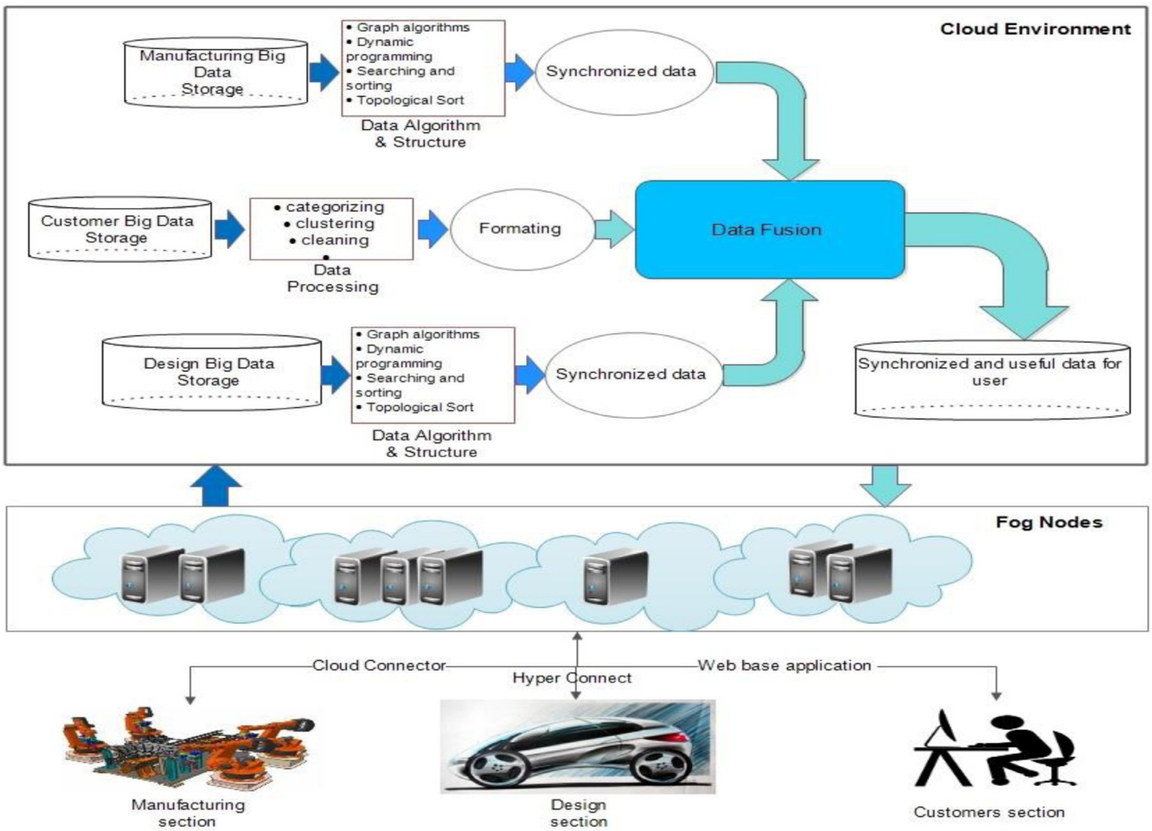

Fig. 8. Data integration and commutation data in the cloud environment.

Table 2
Characteristics of the proposed platform.

Features	[41,62]	[47]	[45]	[44,45]	[58]	Our CDMP
Ability to improve agility	Yes	Yes	Yes	Yes	Yes	Yes
Ability to support distributed system	No	No	Yes	Yes	Yes	Yes
Ability to improve scalability	Yes	Yes	Yes	Yes	Yes	Yes
Ability to support big data	No	No	No	No	Yes	Yes
Ability to support customer views	No	No	No	No	No	Yes
Ability to developed triple direct communication	No	No	No	No	No	Yes
Peer to Peer communication	No	No	No	No	No	Yes
Social Media	No	No	No	No	Yes	Yes
Ability to data integrity	No	Yes	Yes	Yes	Yes	Yes
more trustable	No	No	No	No	No	Yes
Big data process	No	No	No	No	No	Yes

manufacturing knowledge. This step uses BaaS for storing and analyzing design data. After the detailed design, verification, and simulation step start. This step tries to modify product based on customer views if faced with any problems. When the simulation step finished, the manufacturing step starts to manufacture a new product. Also, in this step, customer views knowledge effect to modify the product such as change type of tire, frame material and add specific equipment, etc.

For a better explanation, we consider an example of design and manufacturing special bicycles based on customer requests. The collaboration among different sections via blockchain is also shown in this example.

In this scenario, our customer wants to buy a specific bike for his job. The customer is a deliveryman, and he needs a bicycle to deliver food. He explained his request about the bike as a text file on the website. The platform aims to analyze the text and extract useful information for the design section and manufacturing section. The detailed text is shown in Fig. 10.

The first step is to process these text segments into the sentences. As can be shown, there are nine sentences in the text. The platform implements word segmentation and feature extraction separately for each sentence, that is, feature vector extraction. For example, the extracted word of the first sentence, "I am," "25-year-old,", "delivery man," "from China." These extracted words can be compared with the generated dictionary and get the word frequency. According to the word frequency, the platform calculates feature weight so that we get the keyword in this sentence. In the first sentence, the keyword is "delivery man," and in the whole text, the keywords include "delivery packages," "basket," "collapsible" and according to the extracted keywords combined with a well-trained machine-learning model, the platform utilized SVM algorithm to execute classification. In this review text, the critical information is the customer needs a "basket," and the bicycle should be "collapsible." In addition, the color of the bicycle is "bright." The information is more related to bicycle design. Therefore, these sentences are assigned to the design section and saved in the Fog nodes of the design section. Besides, some sentences are related to manufacturing content. For example, the bicycle is used for "delivery," should "not be too heavy," the "budget of this bicycle is about 800 RMB, and "the life of the bicycle is about 5 years". These requirements are related to manufacturing material and manufacturing costs. So these sentences are classified into the manufacturing section with the use of SVM and saved in the Fog nodes of the manufacturing section. Table 3 shows the classification result.

In order to make a reasonable bicycle design for this review, several perspectives need to be considered. From a conceptual design perspective, the design section needs to generate a new design concept according to customer review—the new design concepts obtained from a previously existing design. Therefore, data fusion provided current design information to the designer because different design concepts

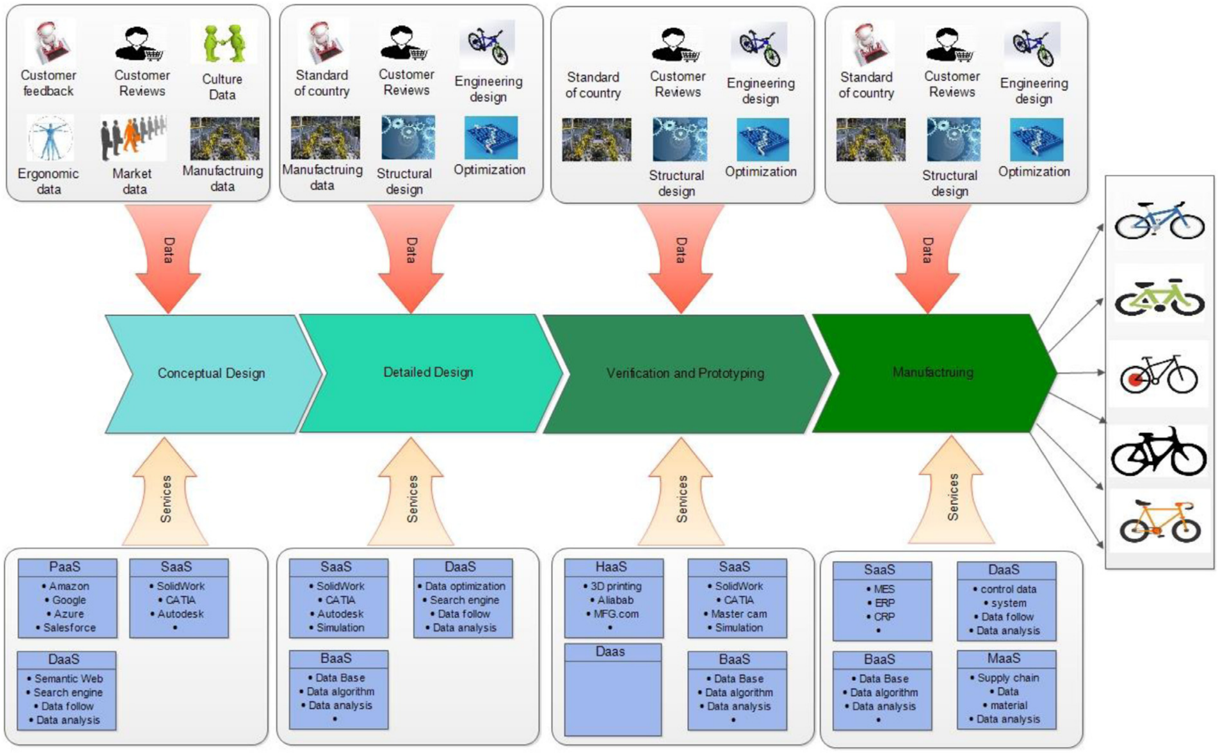

Fig. 9. Illustrative example by considering all data and services on the platform.

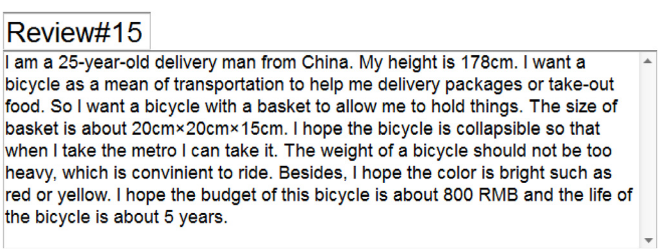

Fig. 10. Example of a customer request for the bicycle.

Table 3
Classification of the customer request example.

	Design section	Manufacturing section
Sentences No.	2,3,4,5,6,8	1,7,9

are helpful for the development of new innovative design schemes.

From a detailed design perspective, the designer needs to confirm the detailed parameters and material of the bicycles. The parameter standard is determined based on design experience and industry specifications. Based on the customer review, the designer should design a basket whose size fulfills the customer's requirements. In this part, the platform provides a basket style database for choosing a suitable basket. The bicycle also needs some collapsible components. Besides, the designer needs to select the appropriate color-matching scheme of the bike.

From a verification and prototyping perspective, the design section makes a prototype as a preliminary design model and uploads it to the fog node. The fog node sends the model data to the repository data and analysis center. The manufacturing section gets this design model from the center and makes verification of the bicycle, including manufacturing feasibility, process complexity, cost, and other evaluation factors. According to the verification result, the manufacturing section gives feedback to the design section. The customer can also receive this feedback via a web application. The verification and prototyping perspectives achieve the interaction and collaboration between the design section, manufacturing section, and customer.

From a manufacturing perspective, the manufacturing section carries out a detailed manufacturing process according to the improved product scheme. To improve production efficiency and guarantee product quality, manufacturing processed by several manufacturing enterprises, that is, collaborative manufacturing among enterprises. Besides, for satisfying the design scheme and customer review, the manufacturer needs components that meet the requirements, which requires collaboration with suppliers. For example, according to the customer review, the bicycle is used for delivery, so the tires of the bicycle should adapt to urban roads. Therefore, the manufacturers should also have collaborated with the supplier to request a better tire for this bicycle. Also, the customer needs a light bicycle. Therefore, there is a particular requirement for the material selection of the bicycle. In this section, the platform provides a material database for selecting a suitable material. The designer chooses appropriate materials for each component from the database so that the weight of the bicycle can satisfy the customer requirement.

To summarize, during the production of the customized bicycle, each sentence of the customer review is firstly classified one by one to determine which part belongs to the design section, and which part belongs to the manufacturing section, then the classified customer review saved in the platform. After that, both the design section and manufacturing section execute the production process based on the classified customer reviews. Also, they collaborate by fog nodes and blockchain. The entire production process fully taps the information of user reviews. The security and connectivity of the communication between these three sections provided by smart contracts, and in this section, we used the following algorithms as smart contracts between each section.

8. Discussion

The proposed platform provides a trustable collaboration with extracting product features and customer effective feedback from customer views and constructing useful product taxonomies based on the information obtained. However, there are some following questions remain for investigation:

(1) How to truly realize the real development and application of the platform?
(2) How to guarantee security during the process of collaboration?
(3) What can other types of services be moved into this platform?

To fill in the gap between current technologies and the proposed platform, it's necessary to discuss how to truly implement technologies into the development and application of the platform. For example, an advanced programming language, the cyber-physical system, can be utilized to develop the platform.

Cyber-Physical Systems (CPS) is a multidimensional and sophisticated system for general computing, network, and physical environments. It realizes real-time sensing of large-scale engineering systems through organic integration and deep collaboration of 3C (Computer, Communication, and Control) technologies, dynamic control, and information services. CPS realizes the integrated design of computing, communication, and physical systems, which can make the system more reliable, efficient, and real-time coordinated. CPS has significant and broad application prospects. In the proposed platform, CPS is helpful for the interaction effects of the interface of different sections, so that the efficiency of the data exchange, data integrity, and data process can improve a lot.

Besides, to guarantee the security of data exchange and prevent the data center from being attacked, some data encryption measures can be implemented during the data transmission such as asymmetric encryption. The asymmetric encryption algorithm requires two keys for encryption and decryption. The two keys are a public key and a private key. Only if the users have two keys, they can get detailed information about the data. The conventional asymmetric encryption algorithm is RSA, Elgamal, backpack algorithm, Rabin, D-H, ECC (elliptic curve encryption algorithm), etc.

Besides, some other services can add to the proposed platform, such as the costing service for the product model. During the collaboration process, cost control is one of the essential items in product development. In our future, we will try to cover these three questions based on real implementation and using novel data exchanges method and utilize a machine-learning algorithm for estimating the cost of the design scheme.

7. Conclusion

In this paper, we discussed and compared the existing CDMP, and we proposed fog and blockchain-based design and manufacturing platform, which covers the customer views from the first stage of design until the manufacturing section and constructs triple direct communication among designers, manufacturers, and customers. We applied the machine-learning method for extracting design and manufacturing knowledge from text. We explained the key features and requirements for implementation.

There are four main contributions to the proposed platform. Firstly, we took into account the feedback of customer in the product design and manufacturing, so that the platform can achieve customer-based product development. Secondly, the proposed platform utilized machine learning method to perform clustering and categorizing customer views. The customer views transferred to design and to manufacture knowledge. Thirdly, fog computing is implemented as the structural support in the proposed platform. The implementation of fog computing promotes the platform with excellent performance in location awareness and low latency. Therefore, the platform can achieve big data processing and storage. Lastly, the platform utilizes a blockchain-based communication network to construct a secure data-sharing environment. The data-sharing rules and authentication are executed automatically based on smart contract modules and node verification. The data transmission is protected, avoiding the risk of data tampering in the public cloud environment.

Finally, in order to evaluate the effect of the proposed platform, we presented the design and manufacturing of the bicycle as the case study. The customer of the bicycle is a delivery man, and he wants a bicycle for his job. With the collaboration among the design section, manufacturing section, and customer, the bicycle design was based on the request.

CRediT authorship contribution statement

Ali Vatankhah Barenji: Conceptualization, Methodology, Visualization, Writing - review & editing, Validation. **Hanyang Guo:** Writing - original draft, Conceptualization, Methodology. **Yitong Wang:** Methodology, Software. **Zhi Li:** Conceptualization, Writing - review & editing. **Yiming Rong:** Supervision, Conceptualization.

Declaration of Competing Interest

Authors declare that he has no conflict of interest.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.rcim.2020.102043.

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