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AI and IoT based collaborative business ecosystem: A case in Chinese fish farming industry

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1 Introduction

Moore (1993) first introduces the term, business ecosystem, as a virtual business community, which is 'supported by a foundation of interacting organizations and individuals – the organisms of the business world.' The term ecosystem is a biological metaphor, suggesting the organism of the business environment and interdependence and 'co-evolution' of the business community over time (Moore, 1996). Members of a business ecosystem may 'fall outside the traditional value chain of suppliers and distributors that directly contribute to the creation and delivery of a product or service', including those indirectly contributing to the value of products or services, for instance, financing institutions, technology and services providers, government, and market (Iansiti and Levien, 2004). Although earlier literature has shown interest in collaborative ecosystem management initiatives (Brody et al. 2006), more recently, Collaborative Business Ecosystem (CBE) has become a more popular term in publications, suggesting that collaboration becomes a unique and inherent attribute of a business ecosystem (Graca and Camarinha-matos, 2017; Wulf and Butel, 2017).

In the digital era, Information Communication Technology (ICT) has formed the technical infrastructure and digital platform for traditional businesses and industries to become more digitalized. As a result, the integrated use of modern technologies such as Artificial Intelligent (AI) and the Internet of Things (IoT) forms the digital business ecosystem (Nachira, 2002; Nachira et al., 2007; Briscoe, 2010). Evidence shows that the digital business ecosystem (Nachira et al., 2007) has developed a more collaborative aspect of the business ecosystem, where co-evolution, value co-creation, and sustainable performance become prominent (Ma et al., 2018).

How, however, are modern digital technologies such as AI and IoT (A-I) supporting and enhancing value co-creative collaboration within a business ecosystem?

How does the A-I based business ecosystem sustain and evolve? Little literature has been found addressing these queries as they are entirely new either as a concept or as a business phenomenon. Hence, this research aims to showcase the mechanism of an A-I based Collaborative Business Ecosystem (A-I CBE). In light of the UN sustainable development goals, we seek to link the use of the available technologies to improve "life below water" by selecting the Chinese fish farming industry as the research context.

The application of advanced technology like AI systems in China, mostly analytical AI systems at this stage, has started penetration into the agriculture industry (Onojeghuo et al., 2018). As an essential part of Chinese agriculture, the traditional fishery aquaculture is facing challenges for a stable and sustainable performance. The problem is due to a few reasons, e.g., natural disasters such as typhoons. There are other reasons for the performance problem. Consumers, for instance, have a concern about the safety and quality of fish due to water pollution, abuse of antibiotics, and poor quality of aquaculture. Because of the physical nature of the work, aquaculture tends to attract lower intelligence workforce. Also, for historical reasons, most of the Chinese fishery farming is small scale, like a manifestation of the slogan "wherever there is water, there must be fish" (Tapiador et al., 1976). The small-scale aquaculture in China is in the relatively primitive state, and there lacks collaboration and networking between feed enterprises, fish farmers, distributors, retailers, and the outside supporters such as financing institutions.

We demonstrate in this study that the A-I CBE is a practical solution to the sustainability issue of the Chinese fish farming industry under discussion. Our research adds contributions to the business ecosystem theory, particularly in value co-creation and sustainability via digital technologies. It also provides practical implications for policymakers and strategic management in applying digital technologies for networking, value co-creation, and sustainable development. This study also contributes to one of the United Nations Sustainable Development Goals (Goal 14 – Life below water) about "conversing and sustainably using the oceans, seas, and marine resources". The remainder of the paper comes as literature review, methods, case analysis, discussion, and conclusion.

2 Theoretical background

2.1 Narrative Perspective

In September 2015, the United Nations (UN) Sustainable Development Summit held in New York approved the agenda of sustainable development by 2030 (UN, 2015). Seventeen goals were set, including no poverty, zero hunger, good health and well-being, quality education, gender equality, cleaning water and sanitation, life below water, and so on. The 17 goals provide a blueprint for peace and prosperity for people and the planet, now and into the future. Academic scholars have started to explore the UN's goals with organizational performance. Extant research suggests that utilizing advanced technology and big data analysis help to achieve these sustainability goals and benefit organizations. For instance, Njuguna and McSharry (2017) suggest that big data analysis is an effective means to obtain regional socioeconomic estimates, continuously monitor the effects of policy, and shape future decisions. Similarly, Malhotra et al. (2018) find that big data analytics applied in governance helps to achieve sustainable development goals in India. In the field of healthcare, Wang and Hajli (2017) reveal in their research that the adoption of big data analysis provides solutions to parallel processing large volumes of data, which enables to identify previously unnoticed patterns in patients related to hospital readmissions. Hence, it consequently supports a better balance between capacity and cost.

2.2 Collaborative business ecosystem and digital technologies

Business ecosystem theory stems from supply chain management and social network theory; the synergy of the relevant literature shapes the study of collaborative networks. Collaborative networks can be found in different sectors and industries such as networks in manufacturing involving suppliers, manufacturers, and consumers and so on, and networks in elderly care connecting care centers, family relatives, and healthcare institutions (Camarinha-Matos and Afsarmanesh, 2008).

There are different levels of collaborative networks, from networking to coordinated networking, and further from cooperation to collaboration (Camarinha-Matos and Afsarmanesh, 2006). Collaboration (i.e., CBE) represents the highest level of collaborative networks, possessing all attributes of the lower levels of networking activities, e.g., communication, information exchange, interaction and adjustment of activities for mutual benefits, and resources sharing for achieving compatible goals in a value chain. Additionally, CBE aims to co-create values between participants within the community (Camarinha-Matos et al., 2009). Moreover, CBE is a long-term strategic alliance; sustainability and evolution of the ecosystem are desirable (Camarinha-Matos and Afsarmanesh, 2008; Camarinha-Matos et al., 2009; Macedo and Camarinha-Matos, 2017).

Literature suggests that with the support of digital technologies such as AI and IoT, the collaborative aspect of a business ecosystem becomes more prominent (Tsatsou et al., 2010; Rong et al., 2013; 2015; Mukhopadhyay and Bouwman, 2018). Barros, Dumas, and Bruza (2005) analyze the rise of web service ecosystems, suggesting the potential to business, 'can interoperate with other services, be composed into long-running business processes, spanning intra- and inter-organizational boundaries, and be procured through different business domains and market sectors.' Rong et al. (2015) apply case studies of the IoT based business ecosystem in the proposed 6Cs model, demonstrating that IoT leads to the evolution of the business ecosystem.

2.3 Value co-creation

Values co-creation is to meet the new requirements of customers and stakeholders through collaborative activities (Camarinha-Matos and Macedo, 2010; Graça and Camarinha-Matos, 2017). Such collaborative activities are generally manifested in the form of collaborative innovation, including business model and technological innovation (Ritala et al., 2013; Radziwon et al., 2013; Schuster and Brem, 2015).

Iansiti and Levien (2004) analyze the competitive advantage of IBM and Microsoft and find that the two giant enterprises implement the strategy of forming their business ecosystem. Being the "core enterprise" of the ecosystem, IBM and Microsoft make constant progress and outperform their competitors in the global ever-growing competitive environment. The core enterprise in the business ecology leads the process of value co-creation, and also attracts non-core enterprises to join and maintain in the ecosystem (Iansiti and Levien, 2004; Rong et al., 2013). Rong et al. (2015) suggest that in the IoT based CBE, IoT facilitates information flow and links all participants of the business ecosystem, and hence the technology and service provider acts as the central enterprise, leading innovation and providing a platform for collaboration of participants in the ecosystem. However, the extant literature lacks a focused study on how AI and IoT support and enhance value co-creative collaboration within a business ecosystem.

2.4 Evolution and sustainability

Abreu and Camarnha-Matos (2006) propose the evolving nature of value systems for sustainable ecosystems; the continuous and collaborative interaction among partners generates value, and it evolves. Camarinha-Matos and Abreu (2007) develop the CBE performance indicators, which consist of the performance of individual entities (e.g., minimization of costs or risks) and evolution as the performance of the collaborative community. Throughout continuous studies made by Camarinha-Matos and other scholars, e.g., Camarinha-Matos and Afsarmanesh (2008), Camarainha-Matos (2009), Camarinha-Matos and Boucher (2012), and Rong et al. (2015), one point is made clear that evolution of a business ecosystem indicates sustainability of the community as a whole.

Moore (1993) describes the evolution of a business ecosystem in the four-stage lifecycle: exploration, expansion, leadership, and self-renewal and extinction. Literature also suggests that increased transparency and enhanced trust indicate the evolutionary performance over time of the CBE (Camarinha-Matos and Abreu, 2007). Trust is not only to reduce the cost of collaboration but also an essential cornerstone of collaborative innovation and an institutional guarantee for value co-creation (Tsatsou et al., 2010; Rong et al., 2015).

Wulf and Butel (2018) demonstrate how knowledge sharing and collaborative relationships in CBE improve business performance, suggesting that among others, the governance and richness of the business ecosystem and social mechanisms influence participants to share knowledge, to innovate and therefore to compete sustainably. Further, Mukhopadhyay and Bouwman (2018) study the platform-based ecosystem and conclude that the platform leader is vital for the governance of the overall healthy ecosystem. However, the extant literature lacks research on how an A-I CBE sustains and evolves in terms of structure and governance of the ecosystem and its development over time.

2.5 Conceptual framework

CBE is a complex, dynamic and collaborative network of participants across supply chains; the inter-organizational collaboration inside a business ecosystem is different from the traditional linear or two-way relationship alongside a single supply chain (Brody, 2006; Camarinha-Matos and Afsarmanesh, 2008). Compared with other forms of collaborative networks (Camarinha-Matos and Afsarmanesh, 2005), CBE is aiming for value co-creation by and for all participating entities, e.g., enterprises and people (Camarinha-Matos and Macedo, 2010; Smith et al., 2014; Mukhopadhyay and Bouwman, 2018). In the digital era, the collaboration of a CBE becomes more prominent with the support of digital technologies such as A-I (Rong et al., 2015). Moreover, a systematic literature review suggests that a healthy CBE is sustainable and evolutionary over time (Graça and Camarinha-Matos, 2017). Hence, drawing on the literature review, we develop our research framework depicted in a cycle chart (Fig. 1)

[Insert Fig. 1 here]

At present, the forefront technology represented by A-I has brought a profound influence on the operation mode of traditional industries. A-I provides a digital platform for collaboration within a business ecosystem (i.e., A-I CBE); A-I CBE relies on intelligent data collection and analysis, making the best use of the IoT platform to co-create value for all participants. Moreover, different from the closed business ecological loop built on the Internet and electronic commerce platform, A-I CBE is an open ecosystem, and it evolves and sustains alongside the lifecycle stages (Ritala et al., 2013; Rayna and Striukova, 2015).

3 Methods

3.1 Sample selection

To investigate how AI and IoT support and enhance CBE performance, we searched the internet and special reports for the evidence of AI application and any sign of business ecosystems as well. We finally identified five ICT-related companies, namely, Suzhou Five-leaf Clove Data Technology Co., LTD., Youzu Network Technology Co., LTD., Hangzhou Zero Vision Culture Creativity Co., LTD., Cloud Education, Zhejiang Celefish Agricultural Technology Co., LTD. After the first round of investigation to Five-leaf Clove Data Technology co., LTD. and Youzu Network Co., LTD. (Suzhou)[1], we found that there lacks evidence of either a typical business ecosystem or substantial AI application in these two companies. The second round of investigation was conducted to Hangzhou Zero Vision Culture and Creative Co., LTD. and Cloud Education Co., LTD. Although there is clear evidence of AI application in the two companies, the influence of digital technologies and networking on CBE was insufficient as expected. While the research team was continuously searching, we also actively attended conferences and events, which were relevant to our research interest.

From the reports of Dr. Jie Shen, the founder, and chairman of Zhejiang Celefish Agriculture Technology Co., LTD. (i.e., Celefish hereafter), we finally targeted the company as the research sample as it fits our selecting criteria. Detailed introduction of Celefish follows in the case study section.

3.2 Data collection

Besides the attendance of the three-hour report by the founder of Celefish, semi-structured and unstructured interviews were conducted for the primary data collection. We conducted nine face-to-face interviews with senior and top management and

[1]We chose Suzhou for our research object because it is an essential modern industrial base in China, with an annual output value of more than 200 billion yuan in high-tech industries.

executives in the sample company and with the other members of the A-I CBE (Table 1). Overall, the interviews lasted 13 hours and 10 minutes[2], resulting in 110,818 words of a transcript from the audio record. We used the voice to text software, iFlytek, to convert the audio record into the text.

[Insert Table 1 here]

To form a triangular verification and secure the content reliability, we also collected secondary data. The secondary data sources include official documentation and registry certificates of the company, media reports on Celefish, available online archives about Celefish, and government supporting policies for innovation of agricultural science and technology enterprises.

4 Case study of AI and IoT based CBE and its evolution

Following Moore's (1993) lifecycle stages of a business ecosystem, we analyze in this case study, the lifecycle of Celefish led A-I CBE in three stages, namely, exploration, expansion, and leadership.

4.1 Establishment of Celefish and exploration of A-I CBE

Celefish was established at Huzhou city, one of the three breeding bases of freshwater fish in China, in June 2015. As an agriculture technology company, Celefish specializes in applying IoT, AI, big data analysis, blockchain, regional chain

[2]. The team conducted field research on Celefish Agricultural Science and Technology Co., LTD. three times from November 22 to December 25, 2018. Accompanied by Mr. Huang Yuqiang, the general manager of Celefish, the research team visited theCelefishcompany and learned of its overall information, the double fish pond ecological breeding model of D-PRAS, IoT ecological fishery technology service platform, innovative operation service mode of "IoT + ecological fishery." The field trip lasted for 5 hours, and the recording was processed into primary data of 64600 words. After learning about the company's operation mode, products and services, enterprise ecology and other information, the team conducted in-depth interviews with Mr. Huang Yuqiang, the general manager of the company, Mr. ShenJiawei, the director of Operation Department, and Mr. Ma Kui, the general manager of Technology Research and Development Department. The interview lasted for 2 hours, and the recording was processed into primary data of 26,362 words.

technologies to fishing services. The initial services that Celefish provides are to install AI intelligent monitoring equipment for fish farmers to monitor the conditions of fish pond water, e.g., temperature, quality, and oxygen, transforming the traditional fish farming into the advanced digital one.

More importantly, Celefish develops the IoT based digital service platform, initially aiming to organize and serve small-scale and scattered fish farmers (report, Uni1). Relying on the IoT based operation service platform and data recorded from the AI monitoring equipment in the fish pond, Celefish provides supervision and the trans-regional services 24 hours a day throughout the year. The services include online monitoring of the water condition, mobility inspection, oxygen linkage control, electric power saving management, big data analysis of the fishing condition, microscope meteorological early warning (via cooperation with Huzhou Meteorological Agency), and pest management. Besides, Celefish innovated a double-cycle fish breeding ecological system. The innovation effectively reduces the pollution of fish pond water. Celefish also helps to improve the breeding performance through collaboration with fish farmers, e.g., by applying technologies and purely physical sterilization, physical filtration, nano-microporous oxygen enrichment, pond bottom cleaning, biological purification of water circulation, and runway isolation (report, Uni1).

As of December 2018, Celefish has possessed more than 30,000 registered users, and around 4,000 among them are paid users. The company has provided services for more than 45,000 acres of fishponds. Celefish has also constructed a demonstration base of high efficient ecological aquaculture using cycling water of 500 acres of fishponds (Interview, Uni2).

Based on the A-I platform, a collaborative business ecosystem had gradually formed after Celefish invited more external participants to join the platform.

4.2 Expansion of participants

As the service and technology provider and the core enterprise in the A-I CBE, Celefish has gathered a large number of fish farmers as their customers and collaborators after one and a half years since its establishment. Using accumulated data of customers and transactions through the A-I technologies, Celefish has established its database during the exploration stage. Entered the expansion lifecycle stage, Celefish aims to attract more members and seek multi-party collaboration, including 'fish farming suppliers, fish farmers, distributors, government, financing institutions, and technology providers' (interview, Uni2). All participants contribute their resources and capabilities to co-create values and improve the performance of the ecosystem (Moore, 1993). The primary challenge of this stage is to form a group of stable CBE members (Attour and Barbaroux, 2016) and to develop transparency and trust to evolve the A-I CBE (Nambisan and Baron, 2013).

In the process of fishery breeding, the expenditure of purchasing fish fry, feed, fish medicine and so on accounts for the majority of the whole farming input, so it is particularly important to introduce high-quality manufacturers to fish farmers and save procurement costs.

We are suppliers for fishery products and invited to become members of the Celefish led IoT platform. The direct connection breaks the estrangement between fish farmers and suppliers, which are more cost-effective for both us [suppliers] and fish farmers. (interview, Uni10)

Celefish integrates not only the resources of suppliers but the fish market, catering industry, banks, and insurance companies into the A-I CBE. The fish farming data recorded by Celefish forms credit endorsement to markets about the ecological quality of the fish products. Hence, the market participants, e.g., distributors and retailers, are invited as the members of the A-I CBE. In order to help fish farmers to obtain bank loans smoothly, Celefish offers recorded data of fish farmers' production and performance as credit basis. The data provides banks with a trustable reference to improve credit guarantee and eliminates information asymmetry between financing institutions and fish farmers. Hence, financing institutions are connected in the A-I CBE. In light of the high risk of fishery aquaculture, Celefish also connects insurance providers in the A-I CBE (interview, Uni8). These are but not all examples of the A-I CBE members.

4.3 Leadership

Through technological support and resource integration, Celefish constructs an AI and IoT based CBE, or A-I CBE, depicted in Fig. 2.

Celefish is not only the resource integrator of the whole ecosystem but also the platform leader and the services provider. Through establishing collaborative relationships between fish farmers, supplier enterprises, financial institutions, and governments, all participants co-create value of fish products and services, which leads to sustainable development and evolution of the ecosystem. (report, Uni1)

[Insert Fig.2 here]

Through the combination of online and offline services within the network, Celefish provides fish farmers with one-stop professional services based on scientific and technologic data collection and analysis, such as water quality monitoring, ecological aquaculture services, agricultural materials supply, science, and technology finance, traceability sales, and environmental treatment of sewage water. In this A-I based platform, Celefish plays a full leadership role of resource integration, effectively managing all participants in the A-I CBE from the aspects of logistics, information flow, capital flow and so on (Zahra and Nambisan, 2012; Mukhopadhyay and Bouwman, 2018).

5 Value co-creation in Celefish's platform-based CBE

Within the A-I CBE, Celefish leads the process of value co-creation via collaboration among the A-I platform participants. In this section, we demonstrate the values co-created inside the Celefish led A-I CBE, including, for instance, cost control, identification, and minimization of risks, water pollution control, and fishery quality control.

5.1 Cost control

With the support of digital technologies, e.g., AI, IoT, blockchain and big data analysis, Celefish builds four systematic platforms, namely, intelligent fishery monitoring service platform, intelligent fishery business management platform, intelligent ecological aquaculture service platform and intelligent fishery big data service platform (interview, Uni4). The effective control of the human cost, power cost, feed cost, and financing cost of fish breeding has played a critical and fundamental role in the value enhancement of the Celefish led CBE.

Before adopting Celefish breeding technology system, fish farmers rely on their breeding experience in oxygen enrichment time, length, feeding time and feeding quantity. Particularly in hot summers, fish farmers often have to get up every two hours at night to inspect fish ponds for oxygen enrichment (interviews, Uni5 and Uni6). Thus, intense-labor involvement indicates a high labor cost. Taking oxygen enrichment and feeding, for example, we can compare the differences in effect between the two farming methods (Fig. 3a and 3b).

[Insert Fig. 3a here]

[Insert Fig. 3b here]

Fig. 3a shows that fish farmers make judgments on the oxygenation production time, duration, feeding time, and feeding quantity entirely referring to their farming experience before the use of Celefish A-I technology system. However, they often fail to figure out the fish pond water quality and purification.

When the pond water quality gradually becomes poor to threaten the survival of fish, we [fish farmers] tend to use many antibiotics to reduce the risk of sick fish. Then, the feed and fish fry waste sink, and antibiotics are adopted, fish pond oxygen reduces, and PH levels of the water exceed the standard required. As water pollution deteriorates, we have to use more antibiotics and fish fry, and increase the frequency of oxygen enrichment, which will finally increase the fish breeding cost and labor cost and form a vicious cycle of poor fish breeding quality. (interview, Uni5 and Uni6)

Fig. 3b presents the fishing mode after the use of Celefish A-I technology system. Water quality monitoring data of the fish pond is collected through the automatic system and updated in real-time transmission to Celefish's financing platform connecting financial institutions and insurance companies in the A-I platform. Meanwhile, other system members such as fish farmers, feed companies, and aquatic markets all have access to fish farmers' breeding data through the platform. Celefish also employs its dual-cycle ecological aquaculture system to automatically improve water purification and circulation based on water quality monitoring data. Oxygen production and feeding are all managed automatically through the platform. As a result, 'the A-I CBE reduces the electricity cost of oxygen production by 30% and increases the utilization rate of feed by 30% during the breeding period' (Interview, Uni4). Because water quality is improved, the use of antibiotics is also effectively curbed.

Fig. 4 indicates the trend chart of the fish pond oxygen, based on data collected on

Celefish led A-I system. It shows that the overall trend is very close for several days, and the oxygen pump is automatically triggered to open or close at the lowest and highest points. The system significantly reduces the costs of labor, power, and other required by fish farming (interview, Uni3). The automatic feeder is connected to the data of the Celefish platform, which calculates the daily amount of feed scientifically according to the specific fish species and breeding environment. The feeding machine will automatically release feed to the pond fish at the set time. The intelligent feeding method improves feed utilization efficiency and reduces feed cost in comparison with traditional human feeding (interviews, Uni3, Uni5).

[Insert Fig. 4 here]

Celefish database indicates that the costs of new fish breeding based on the A-I CBE have reduced substantively.

For instance, the electricity cost needed to increase oxygen is reduced by 30%. The financing cost is reduced by 10%. The use of antibiotics is reduced by 40%. The transaction costs between fish farmers and other platform participants such as banks, insurance companies, feed companies, and government departments reduce accordingly. Also, the feed utilization rate is increased by 30%. (interview, Uni4)

5.2 Risk minimization

Risks of aquaculture mainly refer to the losses and risks caused by natural disasters, diseases of aquatic products, and market price fluctuation (Fig. 5a). The risk that the fish farmer undertakes is the direct risk that aquaculture loss brings. The risk undertaken by banks is the default risk of debts caused by bank loans and financing during the farming period. The risk taken by an insurance company is the risk borne based on the insurance policy. In the traditional fish farming mode, the above risks are closely related to fish farmers' farming experience and weather conditions of the year. Therefore, 'bank, insurance companies, and other financial institutions tend to be very cautious when they make a loan to fish farmers' (interview, Uni7) (Fig. 5a). Risk assessment is a tedious process (interview, Uni8). Also, there is no practical way to control the relevant risks in the traditional fish farming mode (interview, Uni6).

[Insert Fig. 5a here]

After the establishment of A-I CBE (Fig.5b), the aquaculture supplier, insurance company, government, and bank collaborate with fish farmers in the A-I ecosystem. On the one hand, fish farmers report their fish farming data, and quality monitoring data is validated with the platform. On the other hand, banks, insurance companies and feed companies directly offer relevant services to fish farmers through platform data docking. With fish pond data information, the platform identifies and eliminates risk factors in the traditional breeding process, improving the overall value of Celefish A-I CBE.

[Insert Fig. 5b here]

For instance, banks used to be unwilling to loan to underprivileged fish farmers who have not got a historical financial record to demonstrate their ability to repay their loan. However, via the IoT based ecosystem, objective data of fish farmer's production and operation provides banks with the data information that improves credit guarantee, transparency, and trust of fish farmers. When applying for a loan from a bank, the fish farmer will submit the purchase contract signed with Celefish (purchasing fish feed, fish fry, fish medicine, and other relevant business contracts), and agree to sign the entrusted payment agreement. The bank can make sure of the proper use of the fund, realizing the special fund for exclusive use, and reducing the risk of misappropriation of the fund (interview, Uni7).

5.3 Environmental pollution control

Water quality is a critical factor in fish farming as it impacts on food security, ecological conditions, and sustainability (Yu and Wu, 2018). According to China's Environment Statistics Yearbook, agriculture is a top source responsible for water contamination in China, which is much higher than that of the industrial pollution load (Yu and Wu, 2018). There are five essential indicators reflecting water quality: dissolved oxygen, temperature, PH value, ammonia nitrogen, and nitrite. Among them, the three parameters of dissolved oxygen amount, temperature and PH value need to be monitored in real-time, because any deviation in dissolved oxygen amount, temperature and PH value may cause all the fish in the fish pond to face deadly danger within two hours, causing high losses (interview, Uni3). Celefish relies on the A-I technology monitoring water quality of scattered fish ponds (Fig. 6).

[Insert Fig. 6 here]

Water quality monitoring service mainly includes four service modules: dissolved oxygen real-time monitoring service, water quality examination service, equipment maintenance service, and growth analysis service (interview, Uni3). Dissolved oxygen real-time monitoring service depends on 7days*24 hours dissolved oxygen temperature monitoring and warning platform staff when there is anything abnormal with water quality, dissolved oxygen, or equipment. Then the platform staff timely notifies the fish farmer, who can view dissolved oxygen data in real-time through the mobile phone and remote-control oxygen equipment. Water quality examination service covers the installation of hand-held ammonia nitrogen detector, nitrite detector, and PH detector, regular testing and analysis in the fishpond, monthly test analysis report, and early and timely water quality warning. Equipment maintenance service provides free installation of dissolved oxygen equipment, maintenance and cleaning of equipment on-demand, on-site maintenance and replacement of spare parts and other services. Growth analysis service mainly includes aquatic product proofing service, aquatic product production status analysis, bait coefficient analysis, breeding method advantages and disadvantages analysis, and breeding experts' technical guidance and other services. The pollution of water resources caused by aquaculture was effectively controlled based on big data analysis and according services (interview, Uni2).

5.4 Fishery quality control

Double-pond recycling aquaculture system (D-PRAS) is a new ecological breeding mode aiming to achieve "no pollution, no emission, and high efficiency" (interview, Uni4). D-PRAS is independently designed and innovated by Celefish, as shown in Fig.7. The mode applies the technology of pure physical sterilization, physical filtration, nanopores oxygen enrichment, bottom clean, water circulation and biological purification, and runway isolation, turning the existing traditional outdoor pond into ecological breeding zones and ecological purification area by a ratio of 1:1.

Celefish has improved the quality of aquaculture for fish farmers by using D-PRAS fish breeding mode.

It changed the problems of excessive agricultural residues, heavy soil flavor and poor meat quality of traditional aquaculture products, and realized the value co-creation of quality fishery together with fish farmers and consumers — the benefits of a single fish farmer increase about three times (interview, Uni9).

[Insert Fig. 7 here]

The ecological aquaculture technology management services that Celefish provides include an operation and maintenance service and an aquaculture expert service. The operation and maintenance manager inspects the breeding site regularly to maintain the breeding facilities, including checking the isolation device, sewage system, filtration system, water injection and oxygenation system and ecological self-purification system (interview, Uni3) (Fig. 8), and maintains the breeding equipment to ensure the normal operation of the system. Celefish also organizes breeding experts to regularly test the water quality and sample fish in the fishpond and integrates the big data analysis of the platform to scientifically plan the prevention and treatment of fish diseases and the management of water quality, to ensure the ecological breeding.

[Insert Fig. 8 here]

At the same time, Celefish will also employ BasS (blockchain as a service) technology to provide different users with such services as the big data management of technical breeding, tracing, anti-counterfeiting verification. The platform will upload the IoT aquaculture data, supply chain data, and financial data to the blockchain, and the data will never be tampered to ensure privacy and security. A-I technology is used to construct the credit system of aquaculture products to ensure the quality of aquaculture products.

6 Discussion and conclusion

6.1 A-I based CBE is sustainable

As a collaborative network, CBE provides a new perspective for enterprises across industries to cooperate (Mukhopadhyay and Bouwman, 2018). CBE is similar to an industrial cluster, which is not limited to one department, and often includes key participants within a region. So how to bring these key participants together? AI and

IoT based CBE provides an appropriate form for collaborative organizations (Camarinha-matos and Afsarmanesh, 2004). In the AI and IoT based CBE, the core enterprise is the technology and service provider, and other followers play a synergistic role to provide customers with comprehensive services and achieve co-existence and co-prosperity (Gawer, 2014). Regardless of the organizational form, the common goal of enterprises is to sustain and grow in the changing environment. CBE can co-evolve in the changing environment, make members more agile, and develop feasible solutions to the changes (Baldissera and Camarinha-matos, 2016).

In this research, the CBE constructed by Celefish focuses on meeting the needs of fish farmers, including direct needs and derivative needs. In a highly dynamic environment, Celefish cannot independently provide all the products and services for fish farmers. In this context, Celefish cooperates with suppliers, fish market, catering enterprises, banks, and insurance companies to form an interdependent and strictly collaborative network, sharing technology and data resources, expanding the market, and optimizing the overall performance and evolution of the CBE (Baldissera and Camarinha-matos, 2016). Therefore, the construction of the A-I CBE is able to address the challenge and problem of sustainability that traditional fish farmers are facing (interviews, Uni1, Uni2, Uni5, Uni6, Uni9).

6.2 A-I is a crucial technology to realize evolving CBE

Further to the evolution of the IoT based business ecosystem (Rong et al., 2015), our study demonstrates that AI technologies enable digitalization of information and knowledge, which supports and enhances knowledge sharing, trust, and collaboration among the CBE members. Hence, AI and IoT together formulate a healthy and sustainable business environment.

With the rapid development and application of communication technology and the

Internet, the emergence of advanced cooperation platform promotes the refinement of the concept of BE and the emergence of new research fields (Graca and Camarinha-matos, 2017). A-I based CBE is generated in this context. A-I-CBE follows the BE theory of Moore (1993) but emphasizes the concept of A-I. A platform composed of A-I can involve more stakeholders and create a BE rather than just a supply chain network. Therefore, A-I can provide enterprises with a broader vision and cross-industry collaboration (Rong et al.,2015).

In our research, Celefish builds an advanced system platform based on A-I not only to realize intelligent fish farming, but also include suppliers, fish market, catering enterprises, banks, and insurance companies and the government into the CBE, making the connotation and scope of CBE more extensive.

A-I operates at every stage of BE. Efficient connections between enterprises are flexibly established by integrating resources of all subjects and sharing data to reduce risks and enhance the power of sustainable development effectively. As an extended, open network, the A-I-CBE connects all stakeholders, and companies in different industries can promote the value of BE. It ensures the sustainable development of economy, society, and environment by integrating technology and economic and social issues through the application of A-I in practice (Rong et al.,2015).

6.3 A-I based business collaboration facilitates CBE to co-create value

Traditional enterprises believe that as long as their products or services are superior to their competitors, they can gain an advantageous position against fierce competition. In the current dynamic environment, enterprises are no longer able to be independent competitors, but rather part of a highly interdependent and collaborative competitive network (Mukhopadhyay and Bouwman, 2018). Business competition has changed from competition among individual enterprises to co-create value and co-evolve within all members of an ecosystem. More collaborative strategies are needed to solve the related problems of business unsustainability (Tencati and Zsolnai, 2009). As demonstrated in the Celefish led ecosystem, the values are the four aspects of cost control, risk identification and control, environmental pollution control and fishery quality; the values are co-created through close collaboration between Celefish, fish farmers, suppliers, fish market, banks, insurance companies and other stakeholders in the A-I CBE.

Collaboration is a way for enterprises to seek long-term development (Tencati and Zsolnai, 2009) and the critical element of a CBE (Baldissera and Camarinha-matos, 2016). A-I technologies and services provider is the core and leading enterprise, who leads and supports value co-creation among all members in the sustainable evolving ecosystem.

6.4 Conclusion

According to the UN's Global Goals for Sustainable Development, "to ensure conservation of life below water, we all have to take action" including governments, individuals, organizations, and more importantly businesses as they are primarily profit-driven bodies. Building on this statement, we tried to address how modern digital technologies such as A-I are supporting and enhancing value co-creative collaboration within a business ecosystem. We find in this research that collaboration is more prominent in Celefish led A-I based ecosystem. Applied digital technologies could include AI, big data analysis, blockchain, and IoT. These applied technologies support and enhance performance in terms of value co-creation by and for all members of the system. Research also suggests that A-I CBE is sustainable and evolving business ecosystems.

The current research has limitations, which direct further research focuses. First, the research uses a single case study. Research into multiple cases and longitudinal studies are desirable for further understanding of the role of digital technologies and perspectives of business ecosystems such as governance structure of ecosystem and innovation activities (Malhotra et al., 2018). Second, there are new areas to explore. For instance, how participants in digital platforms and networking such as blockchain and Internet of Things build up trust in each other; how they interact and contribute to a sustainable ecosystem; what are the challenges and obstacles facing the sustainable development of an ecosystem; how they disrupt the traditional industries in business models and operations.

References

Abreu, A. and Camarnha-Matos, L.M. (2006) ‘On the role of value systems and reciprocity in collaborative environments’, *IFIP International Federation for Information Processing*. Vol 224, pp.273-284

Afsarmanesh, H. and Camarnha-Matos, L.M. (2008) ‘Enhancing performance in industrial collaborative networks’, *International Journal of Production Research*. Vol. 46 No. 5, pp.1203-1205.

Attour, A. and Barbaroux, P. (2016) ‘The role of knowledge processes in a BE’s lifecycle’, *Journal of the Knowledge Economy*, pp.1-18.

Baldissera, T. A. and Camarinhamatos, L. M. (2016) ‘Towards a Collaborative BE for Elderly Care’, *Technological Innovation for Cyber-Physical Systems*, pp.24-34.

Barros, A., Dumas, M. and Bruza, P. (2005) *The move to web service ecosystems*. BPTrends. [online] available at http://www.bptrends.com/publicationfiles/12-05-WP-WebServiceEcosystems-Barros-Dumas.pdf (accessed 26 December 2018).

Briscoe, G. (2010) ‘Complex adaptive digital ecosystems’, *Proceedings of the International Conference on Management of Emergent Digital Ecosystems*, ACM, 39-46.

Brody, S.D., Cash, S.B., Dyke, J. and Thornton, S. (2006) ‘Motivations for the forestry industry to participate in collaborative ecosystem management initiatives’, *Forest Policy and Economics*, Vol. 8 No. 2, pp.123-134.

Camarinha-Matos, L. M. and Afsarmanesh, H. (2005) ‘Collaborative networks: a new scientific discipline’, *Journal of Intelligent Manufacturing*, Vol. 52, pp. 439-452.

Camarinha-Matos, L. M. and Afsarmanesh, H. (2006) ‘Collaborative networks: Value creation in a knowledge society’, Knowledge Enterprise: Intelligent.

Camarinha-Matos, L. and Afsarmanesh, H. (2007) ‘A comprehensive modeling framework for collaborative networked organizations', *Journal of Intelligent Manufacturing*, Vol.18 No. 5, pp. 529.

Camarinha-Matos, L. M. and Afsarmanesh, H. (2008) 'On reference models for collaborative networked organizations', *International Journal of Production Research*, Vol. 46 No. 9, pp. 2453-2469.

Camarinha-Matos, L. (2009) 'Collaborative Networks Contribution to Sustainable Development', *IFAC Proceedings*, Vol. 42 No. 25, pp. 92-97.

Camarinha-Matos, L., Afsarmanesh, H., Galeano and Molina. (2009) 'Collaborative networked organizations – Concepts and practice in manufacturing enterprises', *Computers & Industrial Engineering*, Vol. 57 No. 1, pp. 46-60.

Camarinha-Matos, L.M. and Macedo, P. Á. (2010) 'Conceptual model of value systems in collaborative networks', *Journal of Intelligent Manufacturing*, Vol. 21 No. 3, pp. 287-299.

Camarinha-Matos, L. and Boucher, X. (2012) 'Sustainable collaborative networks – case studies', *Production Planning & Control*, Vol. 23 No. 4, pp. 237-239.

Gawer, A. and Cusumano, M. A. (2014) 'Industry platforms and ecosystem innovation'. *Journal of Product Innovation Management*, Vol. 31 No.3, pp. 417-433.

Graça, P. and Camarinha-Matos, L.M. (2017) 'Performance indicators for collaborative business ecosystems — Literature review and trends', *Technological Forecasting & Social Change*, Vol. 16 No. C, pp. 237-255.

Iansiti, M. and Levien, R. (2004) 'Strategy as Ecology', *Harvard Business Review*, Vol. 82 No. 3, pp.68–78.

Ma, Y., Rong, K., Mangalagiu, D., Thornton, T.F. and Zhu, D. (2018) 'Co-evolution between urban sustainability and business ecosystem innovation: Evidence from the sharing mobility sector in Shanghai', *Journal of Cleaner Production*, Vol.188, pp. 942-953.

Malhotra, C., Anand, R. and Singh, S. (2018) 'Applying Big Data Analytics in Governance to Achieve Sustainable Development Goals (SDGs) in India', In *Data Science Landscape*, pp. 273-291. Springer, Singapore.

Moore, J. F. (1993) 'Predators and prey: a new ecology of competition', *Harvard Business Review*, Vol.71 No. 3, pp.75-86.

Moore, J.F. (1996) *The death of competition: Leadership and strategy in age of business ecosystems*, Harper Collins Publishers.

Mukhopadhyay, S. and Bouwman, H. (2018) 'Multi-actor collaboration in platform-based ecosystem: opportunities and challenges', *Journal of Information Technology Case and Application Research*, Vol. 20 No. 2, pp. 47-54.

Nachira, F. (2002) *Towards a network of digital business ecosystems fostering the local development*. Discussion Paper, European Commission, Bruxelles.

Nachira, F., Dini, P. and Nicolai, A. (2007) *A network of digital business ecosystems for Europe: roots, processes and perspectives*. Introductory Paper, European Commission, Bruxelles.

Nambisan, S. and Baron, R. A. (2013) 'Entrepreneurship in innovation ecosystems: entrepreneurs' self-regulatory processes and their implications for new venture success', *Entrepreneurship: Theory and Practice*, Vol.37 No.5, pp.1071-1097.

Njuguna, C. and McSharry, P. (2017). 'Constructing spatiotemporal poverty indices from big data', *Journal of Business Research*, Vol. 70, pp. 318-327.

Onojeghuo, A. O., Blackburn, G. A., Huang, J., Kindred, D. and Huang, W. (2018). 'Applications of satellite 'hyper-sensing' in Chinese agriculture: Challenges and opportunities', *International Journal of Applied Earth Observations and*

Geoinformation, Vol. 64, pp.62–86.

Radziwon, A., Bogers, M. and Bilberg, A. (2017) ‘Creating and capturing value in a regional innovation ecosystem: a study of how manufacturing SMEs develop collaborative solutions’, *International Journal of Technology Management*, Vol. 75, pp.73-96.

Rayna, T. and Striukova, L. (2015) ‘Open Innovation 2.0: is co-creation the ultimate challenge?’, *International Journal of Technology Management*, Vol. 69 No. 1, pp.38–53.

Ritala, P., Agouridas, V., Assimakopoulos, D. and Gies, O. (2013) ‘Value creation and capture mechanisms in innovation ecosystems: a comparative case study’, *International Journal of Technology Management*, Vol. 63 No. 3/4, pp.244–267.

Rong, K., Lin, Y., Shi, Y. and Yu, J. (2013) ‘Linking BE lifecycle with platform strategy: a triple view of technology, application and organisation’, *International Journal of Technology Management*, Vol. 62 No. 1, pp.75–94.

Rong, K., Hu, G., Lin, Y., Shi, Y. and Guo, L. (2015) ‘Understanding BE using a 6c framework in internet-of-things-based sectors’, *International Journal of Production Economics,* Vol. 159, pp. 41-55.

Schuster, G. and Brem, A. (2015) ‘How to benefit from open innovation? An empirical investigation of open innovation and external partnerships fostering firm capabilities in the automotive industry’, *International Journal of Technology Management*, Vol. 69 No. 1, pp.54–76.

Smith, D., Alshaikh A., Bojan R., Kak A. and Manesh, M. M.G. (2014) ‘Overcoming Barriers to Collaboration in an Open Source Ecosystem’, *Technology Innovation Management Review,* Vol. 4, No. 1, pp.18-27.

Tapiador, D.D., Henderson, H.F., Delmendo, M.N. and Tsutsui, H. (1976) *Freshwater* *fisheries and aquaculture in China*. FAO Fisheries Technical Paper No. 168. [online] available at http://www.fao.org/3/AC862E/AC862E00.htm#TOC (accessed 6 August 2019).

Tencati, A. and Zsolnai, L. (2009) 'The Collaborative Enterprise', *Journal of Business Ethics*, Vol. 85 No.3, pp.367-376.

Tsatsou, P., Elasluf-Calderwood, S. and Liebenau, J. (2010) 'Towards a taxonomy for regulatory issues in a digital business ecosystem in the EU', *Journal of Information Technology*, Vol. 25 No. 3, pp. 288-307.

Wulf, A. and Butel, L. (2017) 'Knowledge sharing and collaborative relationships in business ecosystems and networks', *Industrial Management & Data Systems*, Vol. 117 No. 7, pp. 1407-1425.

Yu, J. and Wu, J. (2018). 'The Sustainability of Agricultural Development in China: The Agriculture–Environment Nexus', *Sustainability*, Vol. 10 No. 6, pp.1776-1792.

Zahra , S. A. and Nambisan, S. (2012) 'Entrepreneurship and strategic thinking in BEs', *Business Horizons*, Vol. 55, pp.219-229.

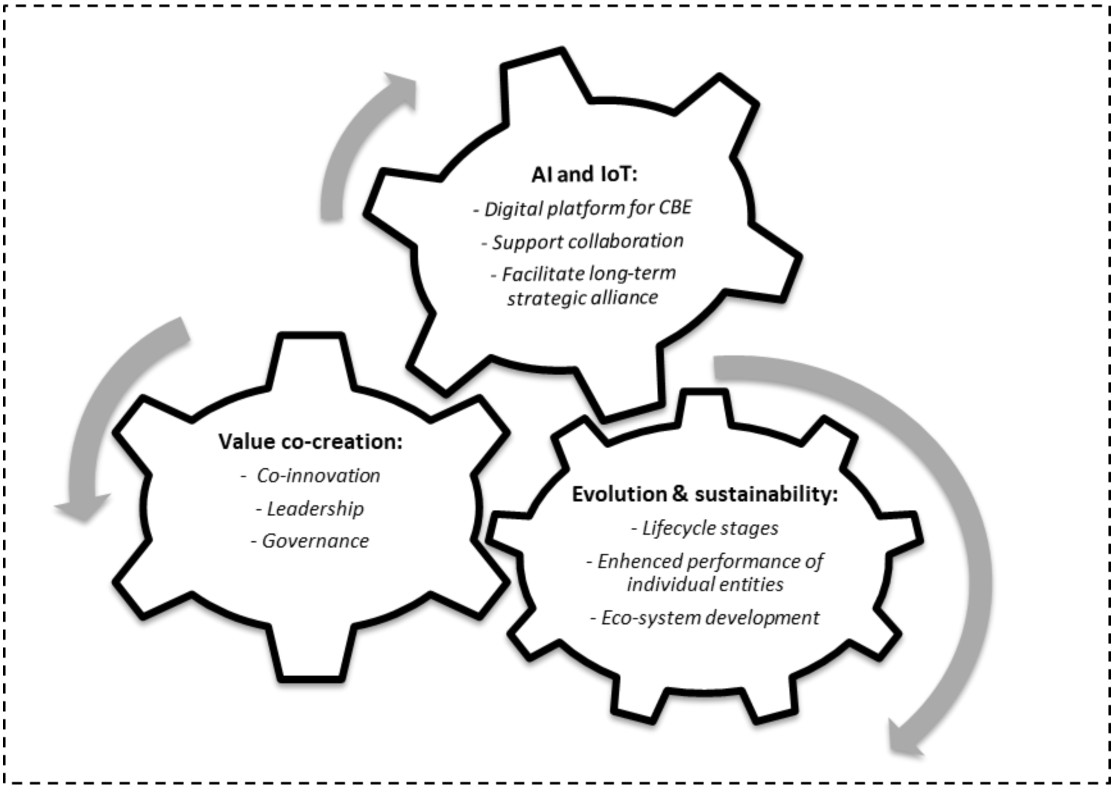

Fig. 1. The research framework for an A-I CBE.

Table 1 Descriptive statistics of participants

Participant	Working Experience	Position	Data source	Duration
Uni1	IoT and AI for over ten years	Founder of Celefish	Special report	3hrs
Uni2	AI for over ten years	CEO of Celefish	Interview	5hrs
Uni3	Management for six years	Operation manager	Interview	1hr
Uni4	IT research and development for over10 years	CTO of Celefish	Interview	1hr
Uni5	Fishery for over ten years	Fish farmer A	Interview	1hr
Uni6	Fishery for over ten years	Fish farmer B	Interview	1hr
Uni7	Banking staff for over three years	Banking staff	Interview	1hr
Uni8	Insurance company for over one year	Insurance company staff	Interview	1.5hrs
Uni9	Fishery association for nearly three years	Fishery association staff	Interview	1.1hrs
Uni10	Feed industry for over two years	Feed company staff	Interview	0.5hr

Note: Ten research participants are coded as Uni1 to Uni10. Uni1 is the founder of Celefish, who presented a special report on the company; Uni2 to Uni10 are coded interviewees.

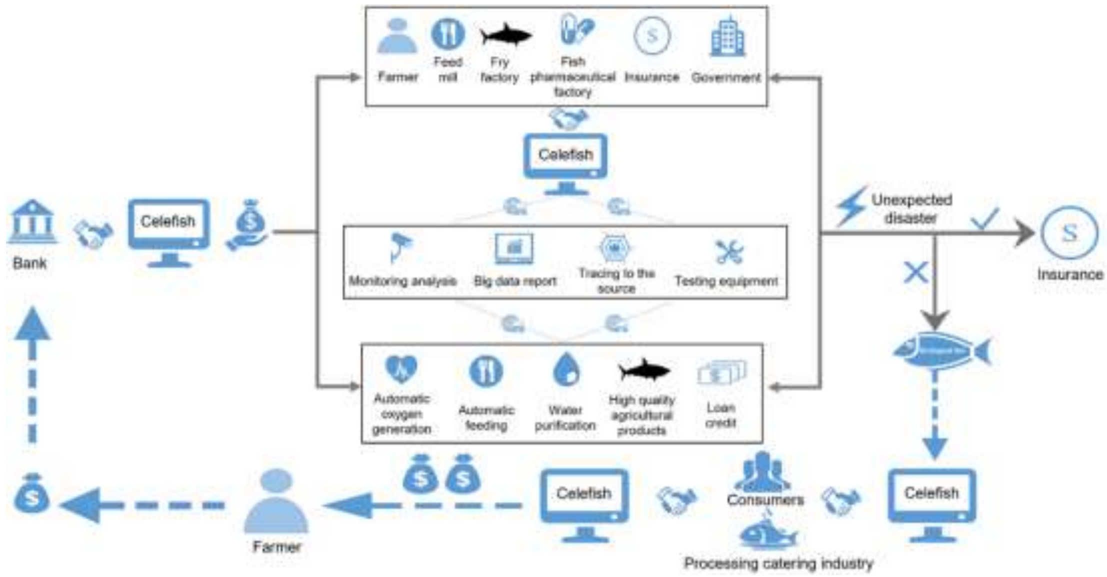

Fig.2. Celefish led A-I CBE

Fig. 3a. Oxygen enrichment and feeding before using the A-I technology system

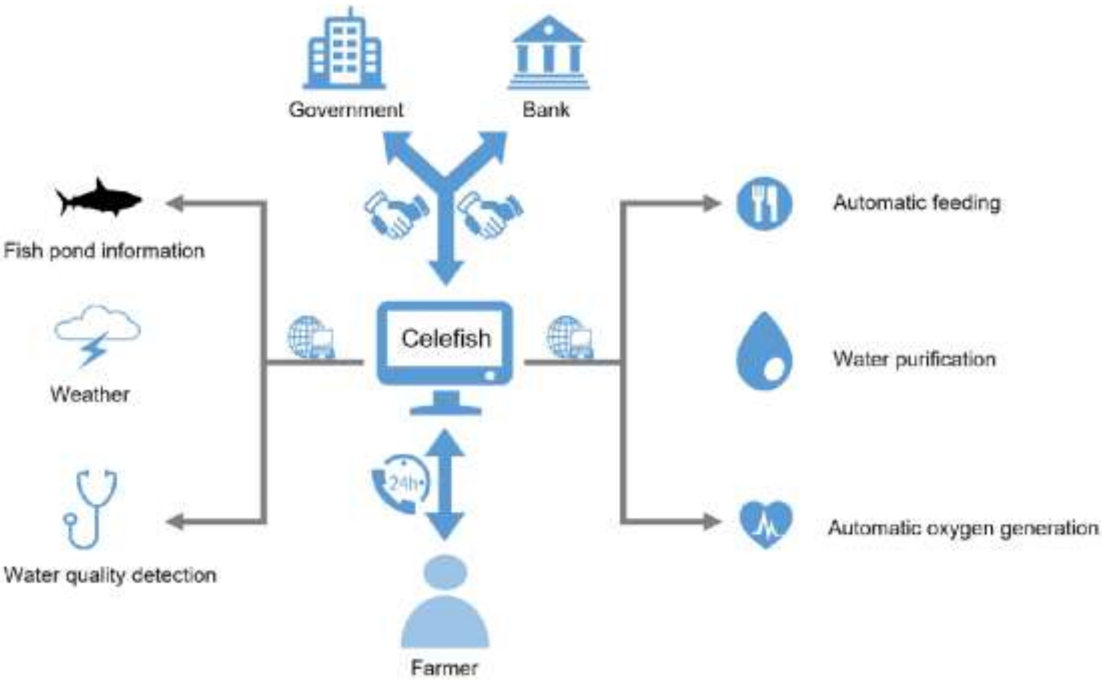

Fig. 3b. Oxygen enrichment and feeding after using the A-I technology system

Fig. 4. Trend chart based on the oxygen detection data in the fish pond

Source: Celefish database

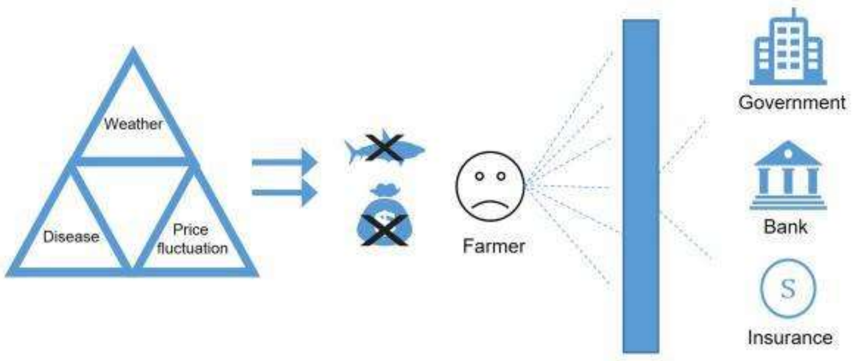

Fig. 5a. Risks in the pre-A-I CBE.

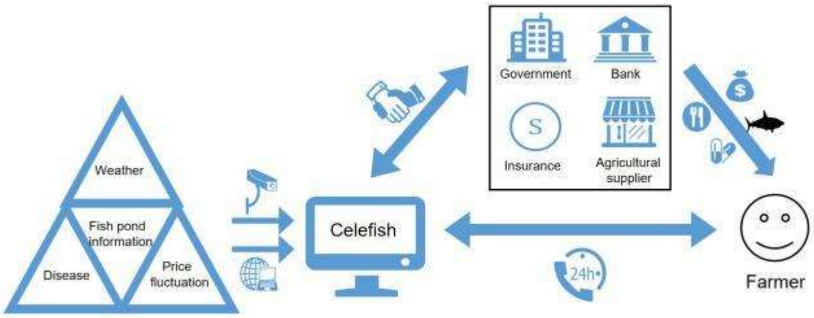

Fig. 5b. Risk control in the A-I CBE.

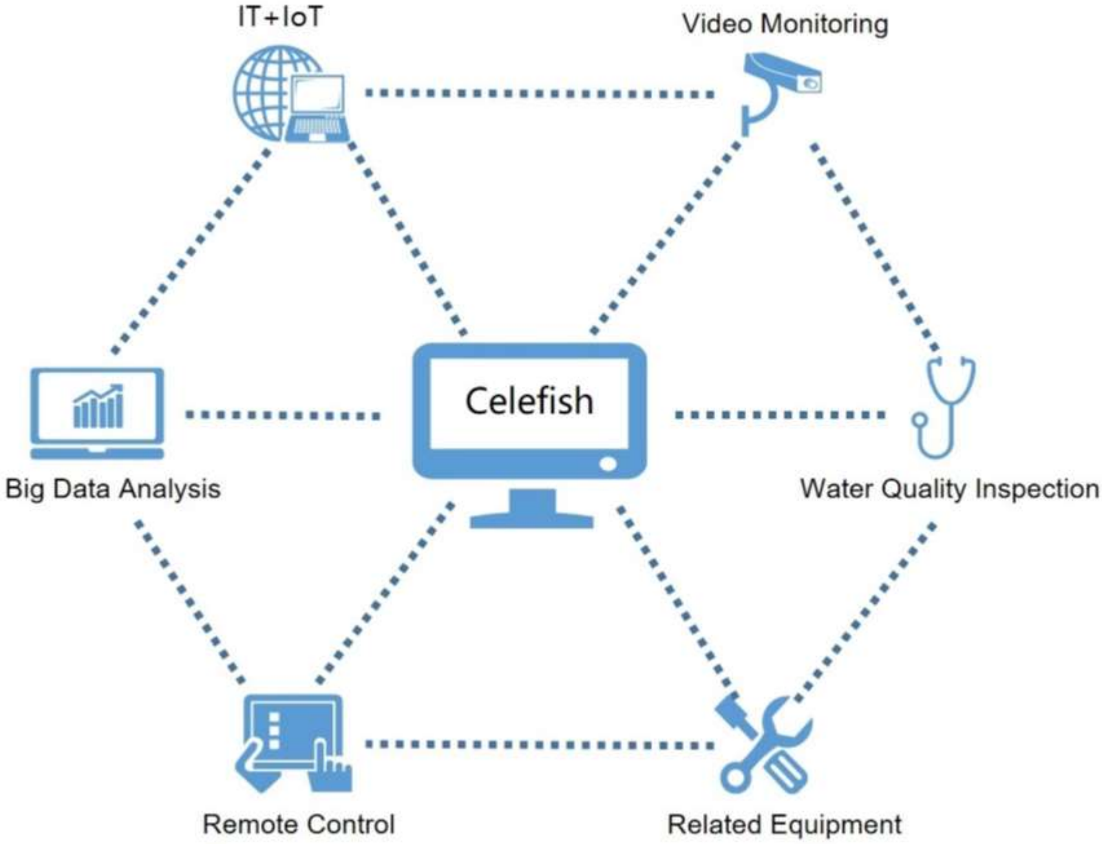

Fig. 6. Water quality inspection for green environment

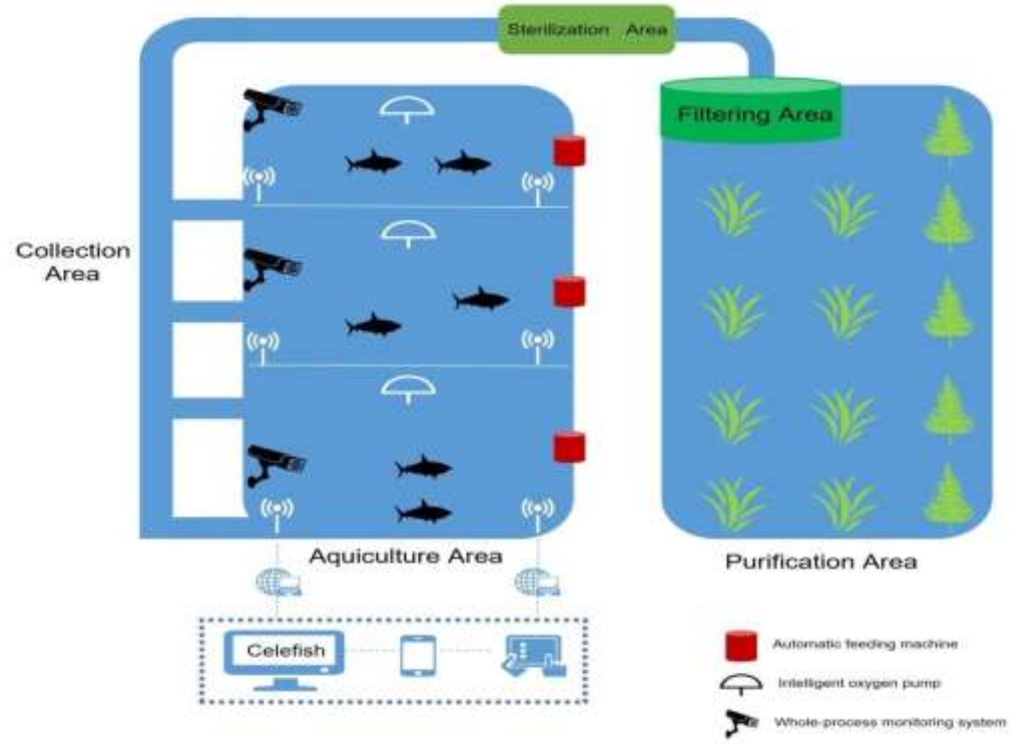

Fig. 7. Celefish's ecological breeding mode.

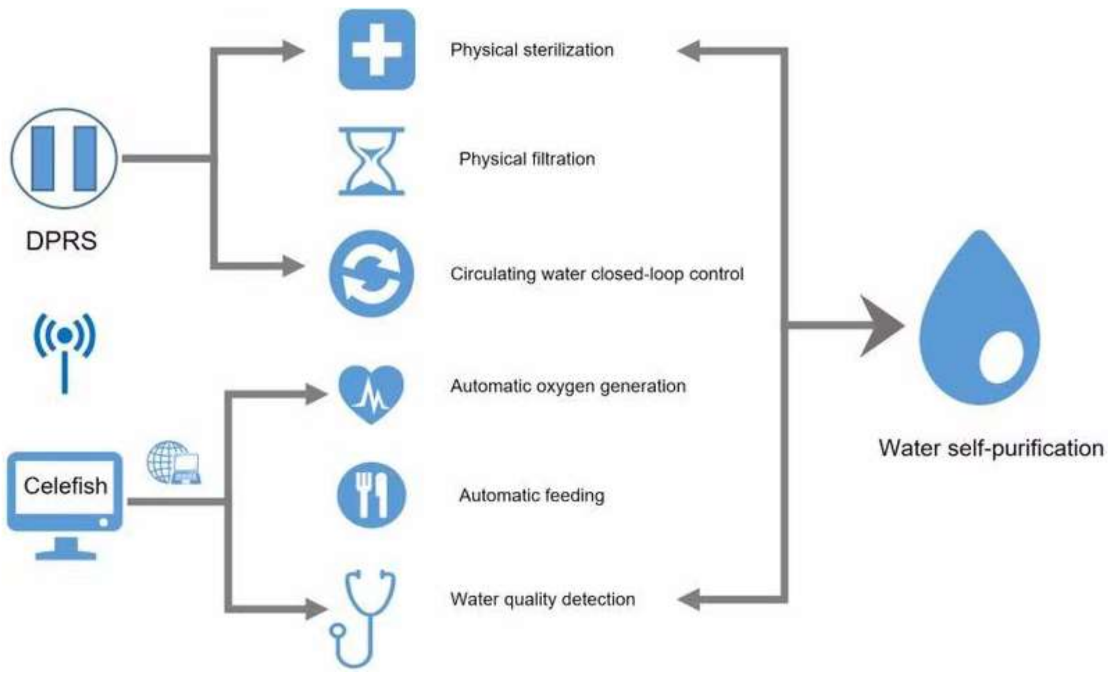

Fig. 8. Celefish's water ecological system.

Note: DPRS = Double-pond recycling (aquaculture) system. Celefish achieves ecological water restoration through spectrum frequency conversion technology, pure physical water ecological restoration technology, pure physical closed sterilization technology, IoT water quality monitoring system, closed-loop control of aquaculture water environment and equipment linkage control system.