Using a bio-inspired model to facilitate the ecosystem of data sharing in smart healthcare

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Abstract. Following the development of Information Technology (IT) techniques, data and the knowledge behind data have been increased exponentially today. The goals to better manage and share such massive big data become more and more critical in many prominent Artificial Intelligence (AI)-based smart industries. Smart healthcare is a typical example in these cases. Efficient management of data sharing apparently can lead to better diagnosis, illness prevention and epidemic monitoring. However, appropriate and robust management of sharing sensitive data among different stakeholders operating within the ecosystem still poses challenges of geographical boundaries and compliance to diverse data sharing and access rules across continents. To address the complexity of large-scale data sharing and provide an efficient solution, our study proposes a bio-inspired autonomic agent-based framework capable of leveraging the large-scale distributed data sharing infrastructure with multiple stakeholders whilst, at the same time, supporting the development of future data integration ecosystems. Our current study selects smart healthcare as a use case to discuss the deployment of our data sharing framework and use this example to demonstrate the potential advantage of this framework but the framework itself also has good extensibility to other interdisciplinary scenarios and domains.

Keywords: Bio-inspired Agents, Evolutionary Computation, Data Sharing

1 Introduction

The exponentially increasing digital data in the recent decades has inspired the research community to revolutionize industrial networks [1]. Multiple data sources in diverse formats had led to the need of establishing data sharing techniques to integrate these sources with secure fashion [2]. The near future aims at integration of data across multiple industrial systems to form a hyperconnected global network. Integration of data across multiple components of a system can be applied in multiple contexts like websites and cloud storages, e-commerce platforms, financial institutions, healthcare systems, land records and so on. The current data sharing models in industries rely on the

internal network of the systems to drive the business opportunities [3]. However, efficient, robust and secure data sharing techniques can unlock huge potentials of the industries in terms of boosting productivity, creating new business opportunities, new customer experiences, accelerating independent research analysis, strengthening collaborations, with minimal resources. Moreover, more and more intensive collaboration based in complex networks even requires the data to be shared across the international industrial boundaries to augment intelligent decisions with full transparency. All of these give us a great challenge and opportunity to implement the capable data sharing framework on a large scale with massive transactions.

One of the main difficulties to build such a framework is the complexity and customized context on large scale data sharing. Many stakeholders in the system can have various requests and standards to collaborate with. To specify all necessary routines and running the daily regulation on such a framework will cost a huge effort which may be infeasible to do in many cases. Here, we try to introduce a bio-inspired model to help people to tackle this problem and build a self-organizing data sharing framework with automatic agents. These agents are evolved by incorporating evolutionary computation concepts mimicking the food chains found in the natural environment. The concrete solution can be accomplished through design of agents for performing key functionalities such as integrating data from diverse sources, embedding personal history of individual patients and user authentication. Some agents can also embed a set of rules for controlling access to information being shared among stakeholders operating within the ecosystem.

This paper discusses the present undergoing work by the authors on how agents can be evolved to manage efficient data sharing within healthcare industries. The deployment of these agents in healthcare and any similar data sharing ecosystem can enable communities of providers by supporting functions that can improve the operations of the entire system.

For instance, in the given healthcare scenario, sharing patient data among healthcare providers can assure smart healthcare services, however, with a probability of health information being misused if leaked across the network. Developing solutions enabling the sharing and integration of data, while preserving security and consent of the users before sharing any data across the network is the need of the hour. This has led to wide use of Electronic Health Record (EHR) systems to integrate patient history, current medications, immunizations, laboratory results, current diagnosis, etc. to develop a centralized network among the healthcare providers. Data integration to facilitate interoperability among stakeholders of the healthcare ecosystem brings in potential advantages for delivering smart healthcare. The patient's medical history can be shared with the doctor in his next visit, the medicines prescribed can be shared with the pharmacist while the bills in the hospitals and labs can be verified and shared with the insurance providers. An agent-based model (ABM) [4] that has been adopted here is a bio-inspired mechanism to automate the systems with interactive processes. This model simulates the internal environments of the systems and produces intelligent decisions on the basis of logical reasoning. ABM systems have the potential to simulate real-world human decisions, behavior, social environments making them robust to be widely used across all domains. With such agents, the system can automate the processes in the

context of data sharing within smart healthcare systems while establishing the consensus of data sharing by massive interactions.

2 Bio-inspired collective agents imitate the food chain model in nature

The sharing issue with multiple stakeholders is common in the biological world and the food chain model can be regarded as one of the most typical examples. In a healthy ecological system, the self-organizing food chain model can perfectly solve and regulate the energy sharing in an extremely complex network while keeping

the flexible equilibrium in the network. According to the previous researches [5,6], the efficiency of the natural food chain model is related to its special construction manner. The model comes from the bottom-up collective interaction of various biological organisms and each kind of organism can be regarded as one kind of stakeholder in the ecosystem. Through the interaction between stakeholders, such a model is self-organized gradually and it can dynamically keep optimized for adapting to the current environment. For achieving similar efficiency and robustness in our data sharing framework, we adopted the same bottom-up construct principles in the bio-inspired agents and use such agents to regulate the communication between these distributed stakeholders in the framework. Each user in our data sharing framework will have their own customized agent which will acknowledge the corresponding user's role in the data sharing. Such knowledge includes the interests of the user, data sharing schema, certification list, the description of resources with the user and so on. The knowledge can be initially given by the user and then automatically evolving by agents. During the data sharing, the agent will interact with other agents based on their knowledge about the particular user to share the data. When a user manually initializes a new transaction or inputs new instructions, the agents are also able to update their own knowledge simultaneously. The updated change on user's attributes will be disseminated through the interaction between agents.

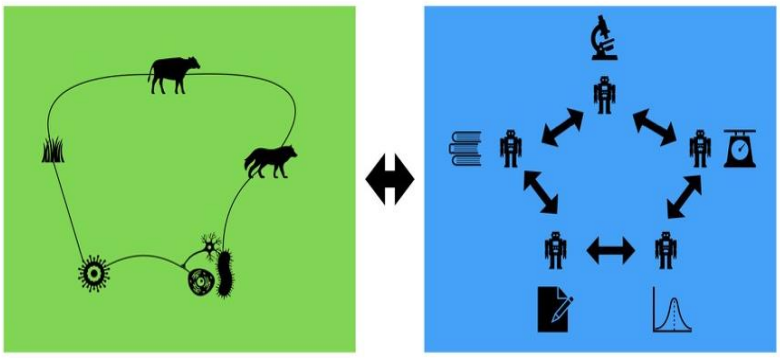

Fig. 1. Analogy of the food chain model and our bio-inspired data sharing framework

3 Self-organizing data sharing framework and dynamic regulation in smart healthcare

Smart healthcare systems are in a position to use digital technology to improve patient outcomes while also improving operational efficiency. Smart Healthcare systems or infrastructures as depicted in Fig. 2 aim at delivering effective services by linking and coordinating the information among the individual components of the system as a whole. Though vast amounts of digital data generated across systems can augment the overall efficiency, they are at stake being leaked across the communication channels [7].

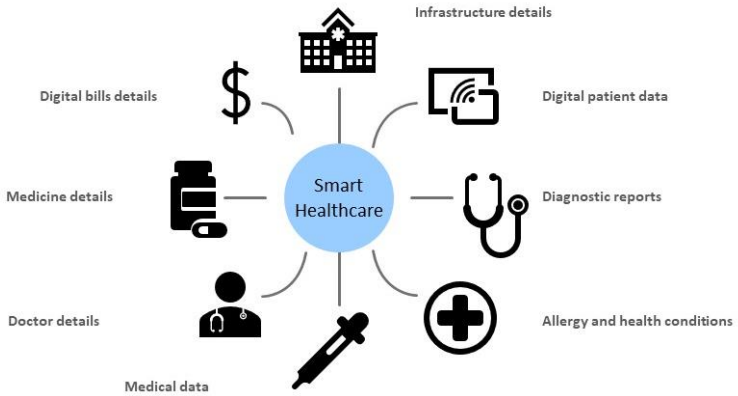

Fig. 2. The components of Smart Healthcare Systems

In our study, we use bio-inspired agents to regulate the data sharing transactions. The knowledge of every user's profile can be updated and regulated through the interaction between agents and knowledge bases. We have applied this framework on the data sharing of healthcare. With a blockchain network, the knowledge of regulating user's data sharing transactions will be well protected and its development is transparent and traceable to all users. The efficiency of the framework can also be improved by the evolvable agents and its particular knowledge. Fig. 3 below shows an example how the bio-inspired agents cooperate with each other in the data sharing of healthcare scenarios.

The proposed architecture is as shown in Fig. 3. There are vast amounts of patient data coming from two primary sources- the patient himself through use of mobile and wearable devices, medical devices implanted during surgical procedures, routine visits for general health checkup to clinics and medical practitioners. The other source is the clinical data associated with the patient such as scans, laboratory results, prescriptions for medications and other service providers belonging to healthcare industries. These data reside in various heterogeneous databases. Various autonomous agents are defined for key processes in healthcare such as: integration of data from diverse sources,

authentication validation among network users, instantiating smart filters among legal entities within the network.

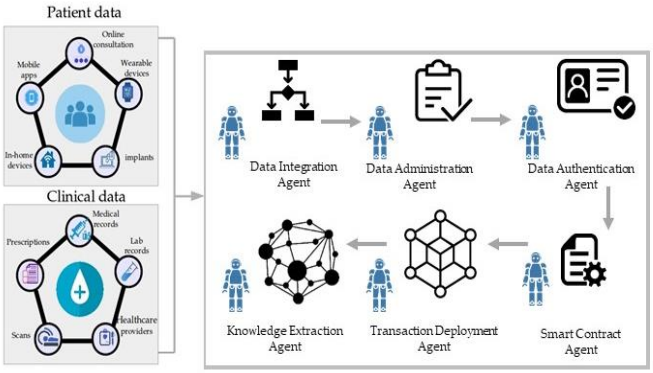

Fig. 3. Different agents within a smart healthcare system

Behind the agents, the system uses the knowledge of knowledge graphs to guide the behavior of each agent. Such knowledge includes the description of smart filters, the path of resources, the consensus of data administration and accessing. Agents can change and update the knowledge or implementing functions on the blockchain, meanwhile all agent's behaviors, changes and data will be recorded and protected in the blocks. As we have discussed above, the whole structure of data sharing framework is based on the interaction of all agents and it can be dynamically changed by altering knowledge of agents. Through an evolutionary algorithm embedded in each agent, the agent can evolve its own behavior model to better adapt to the current given environment for sharing data. All interaction between individual agents and users self-organizes the whole framework from a bottom-up manner.

4 Conclusions

This article described how to use computational bio-inspired agents to access the different distributed datasets and keep the data and knowledge sharing efficient, robust and compatible with all stakeholders in a smart healthcare system. This proposed framework provides a potential interdisciplinary solution for data sharing on many domains where it may need to implement intensive collaboration based on common data. Like the analogy of the natural food chain model, our proposed framework also inherits similar advantages to its biological counterpart. It is capable of dynamically adapting to the customized requests of various users and reaching a consensus through massive interaction. In the next step of this study, we will continually test the framework in a series of subsequent scenarios and initialize the interdisciplinary collaboration with the experts from different domains. Within the future collaboration, we will develop the corresponding benchmark tests based on the expert's suggestion to examine the functionality of the framework.

References

1. Marx, V. The big challenges of big data. Nature, 498(7453), 255-260 (2013).
2. Zhang, Q., Zhang, X., Zhang, Q., Shi, W., & Zhong, H. Firework: Big data sharing and processing in collaborative edge environment. In 2016 FOURTH IEEE WORKSHOP ON HOT TOPICS IN WEB SYSTEMS AND TECHNOLOGIES (HOTWEB), pp. 20-25. IEEE. (2016).
3. Stefansson, G. Business-to-business data sharing: A source for integration of supply chains. International Journal of Production Economics, 75 (1-2, pp. 135-146. (2002).
4. Coyle, J. J., Bardi, E. J., & Langley, C. J. The management of business logistics, 6th ed. St Paul, Minn: West Publishing Company (1996).
5. Mougi, A., & Kondoh, M. Food-web complexity, meta-community complexity and community stability. Scientific reports, 6(1), 1-5. (2016).
6. Schmitz, O. J., & Booth, G. Modelling food web complexity: the consequences of individual-based, spatially explicit behavioural ecology on trophic interactions. Evolutionary Ecology, 11(4), 379-398. (1997).
7. Ferber, J.: Multi-Agent Systems, An Introduction to Distributed Artificial Intelligence. Addison-Wesley, Reading, Great Britain. (1999).