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MetaSyCar: A System for Metabolic Syndrome Control and Caring

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Abstract— **Nowadays, metabolic diseases are of most common health challenges of individuals in different communities that impose significant costs on governments and healthcare systems. In this regard, continuous monitoring of patients and their relatives, collecting real world data and preventive education are important issues that impose high costs and implementation-related problems. Within the recent years, the advent of new technological advancements, including feature-rich smartphones, location-based technologies, Internet of Things and wearables as well as new computing concepts, e.g. crowd computing, put forward new opportunities. However, a remarkable number of efforts still rely on traditional, and relatively less-efficient, approaches. In order to fill this gap in the context of metabolic disease research and performing the aforementioned tasks in the form of an integrated system, in this paper a system for Metabolic Syndrome Control and caring (MetaSyCar) is introduced. The major benefit of the proposed system is to provide a comprehensive and multifaceted monitoring framework in order to track the patients' behaviors, conditions and health indices. Moreover, the system interactivity facilitates the experts' interventions and supervisory considerations. In the paper, the underlying foundations, conceptual architecture and workflow of the MetaSyCar are explained.**

Keywords- Internet of Things; Crowdsourcing; Location-based Service; Gamification; Healthcare Management; Metabolic Disease.

I. INTRODUCTION

Due to risky lifestyle of many individuals in different communities around the world, nowadays metabolic diseases have become more common than any time before. From managerial perspective, dealing with such diseases and their consequences imposes tremendous costs on governments and healthcare systems [1]. In this regard, a great body of the literature is devoted to research on curing and preventing such diseases, including works done in [2]-[3]. Nonetheless, important tasks of continuous monitoring of patients and those who are at high risk of catching metabolic syndrome, collecting real-world data and evidences from patients and other individuals, and preventive education in order to control the disease, are still difficult and costly to tackle. Further, integrating such processes into a specific workflow may be regarded as an impossible mission, especially when it comes to relying on traditional approaches. With respect to the technological advancements, some unprecedented opportunities have been emerged. From individuals' front, a remarkable number of people around the world have equipped with mobile sensors and applications toolkit such as smartphones. On the other side, flourishing the concept of Internet of Things (IoT) [4] and development of wearables, takes the possibilities to a new level. Thanks to the mentioned achievements, many research works have been done in the context of healthcare management, including works done in [5]-[7]. Moreover, leveraging collective human intelligence, in the form of crowdsourcing and human computation, has opened a new window to handle healthcare issues in a more efficient and accurate way [8]-[9].

Inspiring from the mentioned ideas and concepts, in this paper an integrated multi-purpose system for managing metabolic disease-related issues is introduced. The framework is specifically aimed at monitoring patients' behaviors and lifestyles and presenting them general and specific instructions and guides while providing users with a game-like experience. Moreover, users will participate in data collection process in an implicit manner. The main motivation behind the proposed system is to provide an integrated framework to both monitor patients' conditions and lifestyle (possibly in real time) and facilitate medical experts' intervention and supervisory considerations in an (semi) interactive manner. Moreover, since the system takes benefits of current popular technological advancements, e.g. smart gadgets and wearables, the adoption process by the users, i.e. patients, can be less challenging and more efficient.

The authors believe that taking advantages of systems similar to Metabolic Syndrome Control and caring system (MetaSyCar), in addition to encourage individuals to participate in a collaborative healthcare activity, can drastically reduce overhead costs of further managerial tasks to deal with metabolic diseases.

The rest of the paper is organized as follows: the background and motivation are studied in the section 2. In section 3 a brief overview of the system is presented. To provide more information on how the system operates, in section 4 the workflow of the MetaSyCar is overviewed. The conceptual architecture of the system and its different components are described in detail in section 5. Finally, the future works and possible extensions of the project are introduced in section 6.

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II. Background and Motivation

From a merely technical point of view, the rationale behind the concept of crowdsourcing [10] was outsourcing difficult tasks that machines could not handle to a large group of people. In other words, the major benefit of crowdsourcing was leveraging humans' intelligence and cognitive ability. However, due to its numerous applications and facilities, the original concept has been extended for leveraging other abilities of humans to perform tasks such as data collection [11], ideation [12], etc. In this regard, crowdsourcing may be defined as a distributed approach to benefits from individuals' cognitive abilities, knowledge and even their understandings. Following this widely-accepted trend, researchers in the medical science and healthcare management reaped the benefits of such invaluable opportunity in different application areas ([9], [13]). In fact, when it comes to dealing with human-related issues, such as healthcare and wellbeing, relying on their experiences, knowledge and opinions could provide more insightful and accurate outcomes than what may be obtained from small-scale studies and in-lab experiments.

On the other side, the efficiency of modern healthcare systems is strongly related to the amount and accuracy of data gathered from individuals and closer interaction with them. Doing so, leveraging smartphones as a fertile platform to interact with target users is known as working strategy [14]. Also, the data collection process has become easier and more efficient than any time before through leveraging IoT capabilities and facilities [15]. In this regard, wearables play an important role in order to acquire continuous life data [16].

Nonetheless, attracting individuals' participation to take part in such activities is another challenging issue. Dealing with that, many studies have been conducted [17]-[18], though, it seems that besides monetary incentives, taking advantages of gamification, i.e. purposeful games [19]-[20], is a working strategy. Previous studies that followed this approach, specifically those conducted in the field of medical science [21]-[22], could be regarded as strong proofs for its efficiency. Inspiring from the aforementioned concepts, in this work we are presenting a comprehensive, integrated solution to address the following issues:

- Continuous monitoring of patients' behaviors and lifestyles to control and prevent metabolic diseases,
- Collecting data, evidences, experiences and other patients-specific information to support in-lab experiments and studies,
- Facilitating the processes of preventive education and knowledge acquisition in a user-friendly manner,
- Establishing a social network-like platform to encourage users to participate in voluntarily process.

Therefore, and based on popular concepts of crowdsourcing, gamification, location-based technologies [23] and with respect to the facilities IoT can provide, see e.g. [24]-[26], we introduce a hybrid system, MetaSyCar, to integrate and manage all the issues (goals) at once in a single platform. Last but not least, our notion of gamification in this work does not imply to a complete mobile game. Instead, it is only a means to provide an interesting and entertaining user experience to refresh the atmosphere of the mostly unpleasant healthcare-related workflows.

III. System Overview

In this section, different aspects and design considerations of the MetaSyCar will be discussed in details. As mentioned earlier, the system is designed to carry out three main goals of patients monitoring, data collection and healthcare education. Therefore, it could be considered from several perspectives.

Since metabolic diseases are strongly related to daily lifestyle of individuals, an effective monitoring system should be designed in such a way that collects those data. Such data are of two main groups: 1) life data, such as blood pressure and heart beat rate that should be gathered by wearables, and, 2) expressive data, including those that individuals present about their lifestyle, living patterns, experiences, symptoms and so forth. To handle such data, a two-faceted data acquisition system is considered. First, a subsystem is in charge of collecting life data obtained by the wearables and smartphone of individuals. Second subsystem, according to the successful experiences such as PatientsLikeMe [26], is a niche social network in which users share their lifestyle and disease experiences, give themselves some related recommendations and so on. From another perspective, the MetaSyCar is, in fact, an expert crowdsourcing system that implicitly and through a social network-like platform provides opportunity to collect expert and individuals' data, ideas, knowledge, best practices and solutions. Finally, at the top of the architecture, an interface connects individuals to the system. Due to prevalence of smartphones among people, besides their useful features and sensors that come in handy for some purposes, the interface is designed in the form of a mobile application. To be more engaging, the application, in fact, provides users with a game-like experience through which they should perform the designated tasks and submit the results back to the system.

Moreover, the users, based on their activities and submitted information will be provided by medical advices. Such advices are of two classes: those which generated by the system and those which prescribed by professional doctors that participate in the project.

Totally, the MetaSyCar could be described as a:

- crowd computing platform
- special-interest social network
- medical advice system
- mobile application/game

Before delving into different aspects of the system and its architectural details, its general workflow will be explained in the following section.

IV. Workflow of MetaSyCar

In addition to everyone (within a city) who installs the application on his smartphones, the main users of the system are of known metabolic patients and their relatives that based on their medical records are invited to register in MetaSyCar. Just after registration, the users are asked to fill in a questionnaire on their health index; and based on the submitted information they will be classified in three groups: normal, risky and patient. Then, the group-specific instructions will be provided for them to follow. In fact, by installing the application, users participate in a gamified preventative healthcare process where they should follow the instructions and report their adherence to them. Moreover, to help users better track their activities and schedules, some facilities are provided such as reminder notifications and so on. Similar to regular games, users can gain scores and awards based on their functions and performance. Also, as the system is thought to be a type of social network, standard functionalities of such platforms including possibility to follow others and (up/down)voting others' actions are provided. In fact, it would be considered as social incentives that could engage individuals to improve their performance. As mentioned earlier, one of the most important contributions of the MetaSyCar is to provide participants with individual-specific advices and prescriptions as a powerful means to control the diseases. In this regard, in addition to auto-generated instructions that are generated by a medical recommender system based on analysis of users' behaviors and activities, some case-specific recommendations that are presented by professional doctors and experts will be provided to the individuals (Fig. 1.). To increase users' knowledge and information about different aspects of metabolic diseases, several tasks and challenges will be presented to them. Just to name a few, occasional Q&As and quizzes may be mentioned.

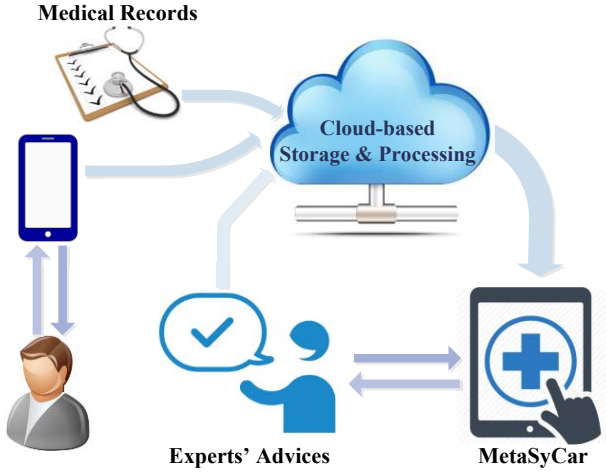

Figure.1. The schematic workflow of the MetaSyCar

Moreover, facilities to acquire users' experiences, viewpoints and ideas on different related topics in the form of game-like challenges are considered.

Inspiring from popular challenges around the social web, the system (and authorized users) may introduce challenges. For example, a given challenge may invite others to do physical exercise in public parks for a week. Since participating in challenges can increase scores of users, their attendance to gyms and parks will be verified by location-based controller embedded in the system. Users' conditions and health indices, also, will be continuously monitored by information acquired from wearables. As a step further, effects of different actions in different time and locations on users' conditions will be collected and analyzed.

For example, walking in a polluted city area in the rush hour may probably affect users' heart beat rate or breathing. Collecting such data, i.e. crowdsensing, provides some invaluable information on environmental effectors on individuals' health. When aggregated and analyzed, such data can feed recommendation system to suggest safe paths to users based on their conditions. According to the aforementioned features, specifically those ones related to sensory data, the acquisition and management, the MetaSyCar is an appropriate solution for smart cities. However, its realization would be advantageous for current regular cities.

V. System Architecture

The general conceptual architecture of the MetaSyCar is illustrated in Fig. 2. Based on this schematic representation, the system is composed on nine major components.

- **Data Storage and Processing**

All the data in the system including interaction and crowdsourced data, user-generated content, as well as system-related log data, etc. are stored in this component. Such invaluable assets may be leveraged for system maintenance and management purposes. Specifically, mining the system-related data provide administrators with priceless insights on different aspects of the system. Moreover, analyzing user-related data could be used to feed recommender system with in-depth information on how individuals could be better helped by to the point recommendations.

- **System Management**

As the heart of this complex system, this component is in charge of managing and synchronizing the cooperation of different parts of the system. To avoid any processing related issues due to overload imposed on this component; it is distributed over the system to manage different parts of the system separately. Nonetheless, a central unit is designed to integrate the distributed managerial tasks.

- **Users Management**

Besides processing and management of users-related procedures, this component undertakes crucial task of connecting infrastructural components with other operational ones and system's interface. Specifically, managing users, their interactions and activities within the system are major contributions of the component. From another point of view, monitoring of individuals' behaviors, adherence to the instructions and totally their lifestyles are performed in this component. Moreover, this component provides supervision and crowdsourcing components with some useful information. Analyzing users' activities and performance will produce required information for supervision component to make decision on how an individual should be instructed. Also, crowdsourcing component needs to have some basic information on users' working habits, their levels of knowledge, participation tendency, etc.

- **Supervision**

This component especially handles managerial tasks and processes. In fact, based on the information provided by other related parts of the system, including users' feedbacks, individuals will be recommended by some instructions and advices. Such instructions are of two main groups: 1) General instructions, and 2) Individual-specific instructions. The former on its own is divided in two classes: global instructions and group-level ones. Such instructions and guidelines originate from two sources. Generally, a recommender system is employed to generate some basic suggestions. However, since there are more complicated cases that need to be investigated by professional doctors, a group of authorized experts continuously participate in the process of diagnosis and prescription. Moreover, taking advantage of expert crowdsourcing, there is a crowdsourcing sub-system for medical experts to analyze individuals' conditions and discussing on prescriptions in order to providing most effective recommendations.

- **Social Network**

As mentioned earlier, to benefit from social nature of the MetaSyCar, a rational choice is building the system on top of a social network infrastructure. In this regard, such a component plays a key role in the system's architecture. However, this social network is transparent from users' point of view; its managerial benefits are considered. Specifically, such infrastructure is in charge of organizing relationships and interactions among users. Moreover, investigation of social networking data will reveal influential factors that caused relationships between certain individuals. Doing so, underlying patterns related to social and psychological reasons of diseases and their effects on patients' behaviors and lifestyles may be inferred. Further, as a city-wide niche social network can be regarded as a small-scale city, the obtained knowledge on individuals' quality of lifestyles and behaviors from the virtual one may be leveraged to implement healthcare policies and programs in real world.

- **Crowdsourcing Component**

To leverage individuals' intelligence and knowledge, the MetaSyCar equipped with an embedded crowdsourcing platform. This platform collects users' data, ideas and experiences in the form of quizzes, Q&As and so on. To handle crowdsourcing related processes such as task organization, results validation and integration, this component receives individuals' information and their submitted results from users management and application component, respectively. Also, to improve the efficacy of the crowdsourcing process, selecting the most appropriate users, i.e. crowd workers/volunteers, is an influential decision. In this regard, a task recommendation engine is employed to match the tasks and individuals based on the features of tasks and users' performance history.

- **Sensory Data Acquisition**

To acquire and manage sensory data, a specific component is introduced. There are two main types of data that the component deals with: 1) environmental data which is gathered by sensors from different places, e.g. parks, streets, etc. 2) Personal life data that is obtained from wearables.

- **Data Fusion**

Since there are different types of data in the system to be used by internal component, they should be integrated and normalized. Doing so, a data fusion component is considered. In fact, heterogeneous input data will be turned into meaningful information blocks after being processed in this component.

- **Mobile Application Component**

As the front-end of the MetaSyCar, this component is in a close relationship with other components, namely crowdsourcing, social network and user management. Two main facilities that this component provides for users to interact with the system are a game-like application and a forum. In fact, participation of individuals in the game and forum considered as a means for collecting their commonsense knowledge, experiences, etc. that will be used to monitor their behaviors and lifestyles. In addition to the system-suggested advices and guidelines, and to make the MetaSyCar more interactive and personalized, facilities for requesting customized recommendations as well as detailed personal assessment are provided. Also, to provide location-aware services, as mentioned previously, the application is prepared with common location manager facilities.

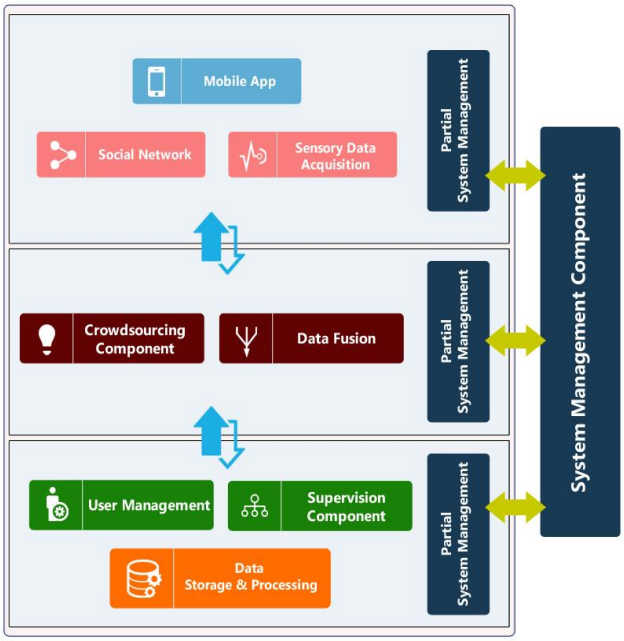

Figure.2. The conceptual architecture of the system

VI. Future Works

When it comes to deal with personal healthcare data, privacy concerns will arise and more strict considerations are needed. In this regard, a comprehensive privacy policy has been regarded for protection of the MetaSyCar against any disclosure of medical information of individuals.

Thanks to the features of the MetaSyCar, to make it more efficient and applicable, some ideas are considered to expand its functionalities. These future works are as follows:

- **Connecting to Smart home:** To take full advantages of sensory information in order to provide users with more accurate recommendations and caring services, connecting the MetaSyCar to the smart homes may be silver bullet. Doing so, almost all of the users' behaviors and actions that may affect their health can be monitored and analyzed.

- **Location-aware search engine:** Leveraging IoT capabilities and crowdsensing process, a large amount of environmental data including effectors on individuals' health conditions can be obtained. As a side service and based on users' experience and professionals' suggestions, a city-wide location-aware search engine can be designed through which individuals can look for, e.g. healthy paths within the city.

- **Real-time Interaction:** In some cases, there are a strong need to real-time and in-the-moment interaction and responses which is not possible in the early stages of the MetaSyCar. Doing so, the number of users and volunteers, both professional doctors and individuals should be reached to a reliable threshold. In this regard, some incentive-based strategies are under examination to attract participations of the community.

- **Becoming Intelligent:** It is expected that by leveraging users participation in generating content, sharing experience, self-reporting, crowdsensing, etc. as well as gold standard provided by experts, the system becomes more intelligent. Such a feature makes the system capable of providing more efficient suggestions and decisions.

VII. Conclusion

Due to emergence to deal with prevalence of metabolic diseases, a monitoring and caring system, entitled MetaSyCar, was introduced in this study. The system took benefit of humans' participation and intelligence as well as IoT capabilities to collect their experiences, ideas, suggestions and environmental data in order to deal with the diseases as well as providing them with more efficient instructions. To attract participation of individuals, the MetaSyCar was designed as a mobile application and provided users with a game-like experience. Moreover, it was designed in such a way that both professionals and individuals can be voluntarily participating in the processes in the form of (expert) crowdsourcing..

References

[1] G. Ricci, et al., "Metabolic syndrome, hypertension, and nervous system injury: Epidemiological correlates," Clinical and experimental hypertension, vol. 39, no. 1, pp. 8-16, January 2017.

[2] F. Saffari, et al., "Metabolic syndrome in a sample of the 6-to 16-vear-old overweight or obese pediatric population: a comparison of two definitions," Ther. Clin. Risk Manag., vol. 8, no. 55, Februray 2012.

[3] K. Shigehara, et al., "Effects of testosterone replacement therapy on metabolic syndrome among Japanese hypogonadal men: A subanalysis of a prospective randomised controlled trial (EARTH study)," Andrologia, vol. 50, no. 1, Februray 2018.

[4] B. Shakerighadi, et al., "Internet of Things for Modern Energy Systems: State-of-the-Art, Challenges, and Open Issues," Energies, vol. 11, no. 5, p. 1252, May 2018.

[5] A. M. Rahmani, et al., "Exploiting smart e-health gateways at the edge of healthcare internet-of-things: a fog computing approach," Future Generation Computer Systems, vol. 78, pp. 641-658, January 2018.

[6] M. Maksimović, V. Vujović and B. Perišić, "A custom Internet of Things healthcare system," Proc. of 10th Iberian Conference on Information Systems and Technologies (CISTI), IEEE, pp. 1-6, 2015.

[7] G. Mokhtari, et.al., “Multi-Residential Activity Labelling in Smart Homes with Wearable Tags Using BLE Technology,” Sensors, vol. 18, no. 3, p. 908, Mar. 2018.

[8] Y. J. Lee, et al., "The application of crowdsourcing approaches to cancer research: a systematic review," Cancer medicine, September 2017. DOI: 10.1002/cam4.1165.

[9] P. McCartney, "Crowdsourcing in healthcare," MCN: The American Journal of Maternal/Child Nursing, vol. 38, no. 6, p. 392, November 2013.

[10] D. C. Brabham, "Crowdsourcing as a model for problem solving: An introduction and cases," Convergence, vol. 14, no. 1, pp. 75-90, Februrary 2008.

[11] G. A. Sigurdsson, et al., "Hollywood in homes: Crowdsourcing data collection for activity understanding," Proc. of European Conference on Computer Vision, Springer, pp. 510-526, 2016.

[12] B. Schemmann,et al., "Crowdsourcing ideas: Involving ordinary users in the ideation phase of new product development," Research Policy, vol. 45, no. 6. pp. 1145-1154, July 2016.

[13] Z. Meisel,et al. "Crowdsourcing healthcare costs: Opportunities and challenges for patient centered price transparency," Healthcare, vol. 4, no. 1, pp. 3-5, March 2016.

[14] X. Wu, et al., "Analysis of smartphone user mobility traces for opportunistic data collection in wireless sensor networks," PMC, vol. 9, no. 6, pp. 881-891, December 2013.

[15] R. Pivare, et al., "Towards internet of things (iots): Integration of wireless sensor network to cloud services for data collection and sharing," arXiv preprint arXiv:1310.2095, October 2013.

[16] M. Schickler,et al., "Using wearables in the context of chronic disorders: Results of a pre-study," Proc. of IEEE 29th International Symposium on Computer-Based Medical Systems (CBMS), , pp. 68-69, 2016.

[17] X. Zhang, et al. "Free market of crowdsourcing: Incentive mechanism design for mobile sensing," IEEE Trans. Parallel Distrib. Syst., vol. 25, no. 12, pp. 3190-3200, December 2014.

[18] D. Yang,et al. "Crowdsourcing to smartphones: Incentive mechanism design for mobile phone sensing," Proc. of the 18th annual international conference on Mobile computing and networking, pp. 173-184, 2012.

[19] A. L'Heureux, et al., "A Gamification Framework for Sensor Data Analytics," Proc. of IEEE International Congress on Internet of Things (ICIOT), pp. 74-81, 2017.

[20] F. Jalili, M. Moradi and M.R. Keyvanpour, "CollegeCare: A location-based game for university maintenance," Proc. of 5th Iranian Joint Congress on Fuzzy and Intelligent Systems (CFIS), IEEE, pp. 75-80, 2017.

[21] J. M. Font, A. Hedvall and E. Svensson, "Towards Teaching Maternal Healthcare and Nutrition in Rural Ethiopia through a Serious Game," Extended Abstracts Publication of the Annual Symposium on Computer-Human Interaction in Play, ACM, pp. 187-193, 2017.

[22] Z. Lv, et al., "Serious game based personalized healthcare system for dysphonia rehabilitation," PMC, vol. 41, pp. 504-519, October 2017.

[23] B. Rao and L. Minakakis, "Evolution of mobile location-based services," Communications of the ACM, vol. 46, no. 12, pp. 61-65, December 2003.

[24] N. G. Hallfors, et al., "Graphene oxide—Nylon ECG sensors for wearable IoT healthcare," Proc. of Sensors Networks Smart and Emerging Technologies (SENSET), IEEE, pp. 1-4, 2017.

[25] S. Kim, and S. Kim, "User preference for an IoT healthcare application for lifestyle disease management," Telecommunications Policy, Volume 42, Issue 4, pp. 304-314, May 2018.

[26] M. Haghi, K. Thurow and R. Stoll, "Wearable devices in medical internet of things: scientific research and commercially available devices," Healthcare informatics research, Vol. 23, No. 1, pp. 4-15, January 2017.

[27] C. Smith,et al. "PatientsLikeMe: Consumer health vocabulary as a folksonomy," Proc. of American Medical Informatics Association annual symposium, AMIA, p. 682, 2008.