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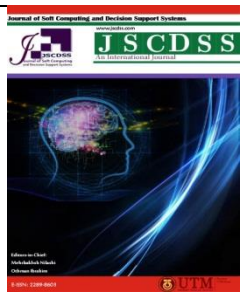

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Intelligent Recommender Systems in the COVID-19 Outbreak: The Case of Wearable Healthcare Devices

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Abstract

Since social and environmental conditions have been changed dramatically in recent years, the spectrum of diseases caused by infections is also changing at a rapid pace. The Internet of Things (IoT) is a new concept which enables users with wearable devices to monitor healthcare. Wearable devices have attracted a great deal of attention and popularity among academics and industry in the last decade. The potential of wearable technology has previously been proven in improving health efficiency and reducing healthcare costs. Wearable devices are believed to be of a very strong value, both for detection and for the tracking and control of the spread of infectious diseases such as COVID-19. Regardless of the importance of wearable devices, only a few number of studies have revealed the usefulness of wearable devices in COVID-19 outbreak. As many of people are not aware of wearable health devices advantages as a mean of tracking their health, as well as using online health communities in critical conditions with limited access to the doctors in hospitals, these types of healthcare technology should be widely introduced and advertised through online retailing shops to improve the individuals' awareness and knowledge of these devices. This can be effectively done by knowledge sharing through social media and intelligent agents in online retailing websites. One of the intelligent systems in online retailing websites is recommendation agents which would be helpful in this situation. In case of wearable health devices to be recommended to the users the in the event of outbreaks, the recommendation systems in online retailing websites must be adaptable and aware to the event of outbreaks and consider the users' demands in this situations. This study aims to investigate the advantages of wearable devices in the event of outbreaks or disasters for healthcare. In addition, the role of recommendation agents in introducing and recommending these devices is explored. Finally, this study reveals some shortcomings of current recommendation agents and provides appropriate solutions for effectiveness of these systems in the event of COVID-19 outbreak.

Keywords: Recommender Systems, COVID-19 Outbreak, Wearable Healthcare Devices, Recommendation Agents, Internet of Things, Artificial Intelligence

1. Introduction

Since social and environmental conditions have been changed dramatically in recent years, the spectrum of diseases caused by infections is also changing at a rapid pace (Control, Prevention, & Diseases, 1994; Petney, 2001; Price-Smith, 2001). The outspread of COVID-19 that was already known as 2019-nCoV has resulted in an emergency situation across the globe with heavily impacts on the global health (Nilashi, Samad, Yusuf, & Akbari, 2020; Torales, O'Higgins, Castaldelli-Maia, & Ventriglio, 2020), including mental health and significant effects on the population's lives, families as well as societies, leading to concerns by World Health Organization (WHO) (Sohrabi et al., 2020). The virus has considerably threatened the public health and contributed considerably to the increase in the expenses of the healthcare.

The Internet of Things (IoT) is the new concept which enables users with wearable devices to monitor healthcare (Ahmadi et al., 2018; Rahmani et al., 2018). IoT is a network of physical objects that are supported by embedded data communication and sensor technology, so as to interact with the states and environment of both internal and external objects (Haghi, Thurow, & Stoll, 2017). Wearable devices have attracted a great deal of attention and popularity among academics and industry in

the last decade (Asadi, Abdullah, Safaei, & Nazir, 2019; Asadi, Rezvani, Khosravi, & Heidarzadeh, 2019; Asadi, Safaei, Yadegaridehkordi, & Nilashi, 2019). The potential of wearable technology to improve health efficiency and reduce healthcare costs has been proven. In a report by (Statista, 2020c), the results of a survey question asking the consumers in England regarding the usefulness of wearable health devices in monitoring glucose, heart rate, physical activity, sleep or weight showed that 77% of the them find wearable technology helpful in the management of their health and communication with health professionals. In another report in (Statista, 2020d), the results of a survey on individuals seeing benefits by using health wearables in Norway in 2018 showed that the most common benefit that health wearable users saw was to understand their own health condition, which amounted to 75% of respondents. Overall, understanding of the health condition has been the main motivations among the U.S. adults that believed wearable technology were helpful for select aspects of health as of 2018 (Statista, 2020a). It is expected that the total digital health market in the United States reach 90 billion U.S. dollars in 2022 (Statista, 2020b).

Wearable devices have been widely used in healthcare context such as influenza surveillance using wearable mobile health devices (Konty et al., 2019), quantifying influenza-related outcomes among the patients with Type 2 diabetes (Samson et al., 2018), improving state-level real-time influenza-like surveillance (Radin, Wineinger, Topol, & Steinhubl, 2020), weight loss (Granado-Font et al., 2015), Parkinson disease (Giansanti, Macellari, & Maccioni, 2008), measurement of heart rate and respiratory rate (Chiarugi et al., 2008), monitoring of human falls (Lin, Hsu, Lay, Chiu, & Chao, 2007), and patients with end-stage renal failure (Davenport et al., 2007). The wearable health monitoring systems that use medical sensors in-home and outside the hospital can help residents and caregivers by continuous and non-invasive health monitoring with minimal doctors' and patients' interaction (Lee & Chung, 2009).

Wearable devices are believed to be of a very strong value, both for detection and for the tracking and control of the spread of infectious diseases such as COVID-19. In addition, according to the World Health Organization (WHO) reports, COVID-19 signs vary from fever to breathlessness. Therefore, changes in temperature, lung function and body fluid analysis for other specific tests are parameters of interest for medical professionals. These are the measures that hospitals around the world take to identify those who have the virus infected. The idea is that wearable devices can improve the individuals' awareness in response to the environmental and health threats with regard to the COVID-19. These devices allow doctors and nurses to respond more quickly to COVID-19 patients' needs and, where necessary, transfer them from the community to the hospital, as well as to reduce the healthcare workers' exposure to the coronavirus. Reducing contact among quarantine workers and healthcare workers also restricts the use of inadequate personal protective equipment. They can also be effectively used in improving risk awareness among the individuals in the healthcare.

Regardless of the importance of wearable devices, only a few number of studies have revealed the usefulness of wearable devices in COVID-19 outbreak (Allam, Dey, & Jones, 2020; Allam & Jones, 2020; Eccleston et al., 2020; Kapoor, Guha, Das, Goswami, & Yadav, 2020; Keesara, Jonas, & Schulman, 2020; Lakkireddy et al., 2020). In addition, inadequate research focused on the drivers and factors impacting the intention to use of these technologies during the in the event of outbreaks or disasters such as COVID-19 outbreak. As many of people are not aware of wearable health devices advantages as a means of tracking their health, as well as using online health communities in critical conditions with limited access to the doctors in hospitals, these types of healthcare technology should be widely introduced and advertised through online retailing shops to improve the individuals' awareness and knowledge of these devices. This can be effectively done by knowledge sharing through social media and intelligent agents in online retailing websites. Online retailing websites such as Amazon.com has dedicated effective product sections for wearable technology of healthcare devices (see Fig. 1). Such devices are recommended in the health news websites to be used for COVID-19 tracking (see Fig. 2). In addition, in Amazon.com, the wearable healthcare devices are introduced with complete information including device description, device information, device applications for individuals' health, and customers' reviews on the wearable devices.

However, in the event of outbreaks or disasters they need to be refined with high priority from the retail product datasets. One of the intelligent systems in online retailing websites is recommendation agents (Abumalloh, Ibrahim, & Nilashi, 2020; Gedikli & Jannach, 2013; Jannach, Karakaya, & Gedikli, 2012; Jannach, Zanker, & Fuchs, 2014; Nilashi, Jannach, bin Ibrahim, Esfahani, & Ahmadi, 2016) which would be helpful in this situation. Recommendation agents have shown their potential in discovering new products that meet users' personalized interest (Nilashi, bin Ibrahim, Ithnin, & Sarmin, 2015; Nilashi, Ibrahim, & Bagherifard, 2018; Nilashi et al., 2016). In case of wearable health devices to be recommended to the users the in the event of outbreaks, the recommendation systems in online retailing websites must be adaptable and aware to the event of outbreaks and consider the users' demands in this situations.

In this regard, it is believed that current types of recommendation agents may not be suitable and will not recommend the specific wearable health devices to the users. In the other hand, the current recommendation agent algorithms may follow their procedure to recommend the products based on the users previously liked or purchased products. Accordingly, some improvements or adaptability changes with context in recommendation agents are needed to consider the products in a specific condition. Traditional recommender systems, such as content based and collaborative filtering systems (Nilashi, Bagherifard, Rahmani, & Rafe, 2017; Rashidi, Hussin, & Nilashi, 2015),

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tend to use quite simple user patterns. For instance, user-based collaborative filtering models the user generally as a vector of item rates (Nilashi, bin Ibrahim, & Ithnin, 2014a, 2014b; Nilashi, Ibrahim, Ahmadi, et al., 2018; Nilashi, Ibrahim, Ithnin, & Zakaria, 2015). As further observations are made on the preferences of users, user models are extended and the entire range of user choices are used to generate product recommendations. The idea that users interact with the system within a specific context is thus ignored by this approach, which means that preference for products within one context might be different from those within another context (Adomavicius & Tuzhilin, 2011).

In this situation, context-aware recommender systems (Liu & Aberer, 2013; Panniello, Tuzhilin, & Gorgoglione, 2014; Verbert et al., 2012) may help retailing websites for more adaptable recommendations. In addition, traditional recommendation agents normally only consider the ratings in user-item matrix to make predictions and recommendations. When rich contextual information is available, providing a new information dimension for recommendation can make the recommender system more effective. Such these types of recommendation agents in retailing websites can better recommends the products such as wearable health devices in the event of outbreaks. The contextual information can be into two categories (Liu & Aberer, 2013), static context and dynamic context. With regard to the static context, user and product characteristics such as user' age, user' gender, wearable device' size, wearable device' options and wearable device' brand are considered in recommendation agent process. With regard to the dynamic context, instantaneous information (e.g., user mood, user location, user health problem) is included to a rating in recommendation agent process. The contextual information can be further included by online social networks to improve recommendation quality. In addition, in COVID-19 outbreak, as many users are involved in sharing the experiences regarding the use of wearable devices and health issues regarding the symptoms of the virus in online social networks, it would be beneficial to utilize such information in the process of recommendation agents. Beside utilizing context-aware recommender systems, the retailing website recommendation system can be further effective through consumers' electronic word of mouth (eWOM) in the event of outbreaks for individuals who are not aware of the advantages of wearable health devices. Sharing the consumers' eWOM can be considered as a critical factor in consumers' decision to purchase (Nilashi et al., 2019). The previous research on customer' behavior analysis shows that eWOM can improve the customers' awareness in the decision making (Ahani et al., 2019; Moran & Muzellec, 2017; Nilashi et al., 2019). In COVID-19 outbreak, consumers' eWOM on wearable health devices may further show its effectiveness in individuals' awareness and decision making. Implementation of eWOM in the process of recommendation agents in the event of outbreaks makes the retaining websites more robust in predicting individuals' health-related demands. Overall, extracting contextual information from the customers' eWOM and integrating this information with the context-aware recommendation agents is possible to further improve the retailing websites efficiency in the event of outbreaks or disasters. Accordingly, the recommendation agents' algorithms should be adaptive to various contexts and customized for the specific problem and condition (e.g., outbreak events) from retailing website and user sides to involve new contextual information for accurate and high quality recommendations.

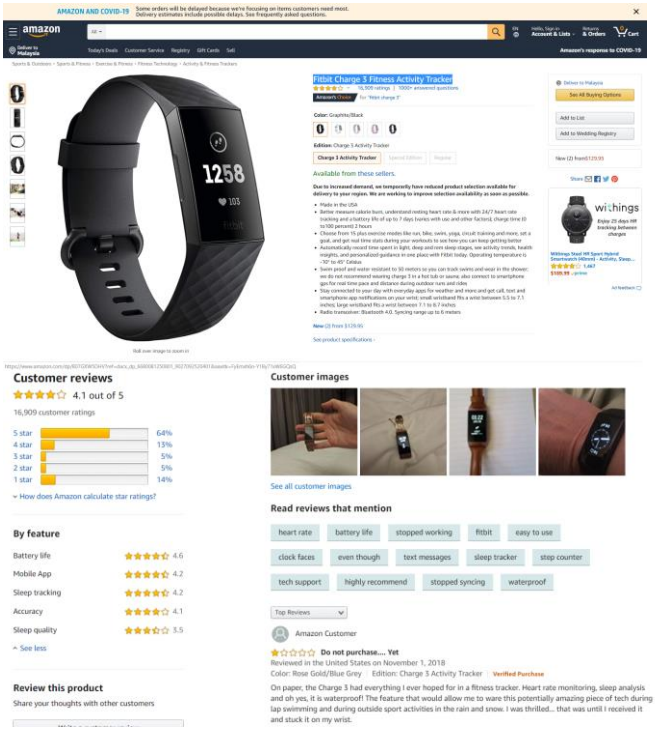

Fig. 1. Amazon.com and the wearable health devices

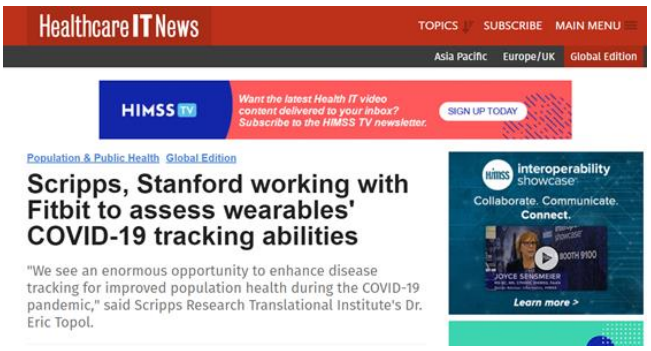

Fig. 2. Healthcareitnews.com and the use of wearable health devices for COVID-19

2. Conclusions

This study aimed to investigate the advantages of wearable devices in the event of outbreaks such as COVID-19. Knowledge sharing through social media and intelligent agents such as recommendation agents in online retailing websites can improve the users' awareness for the benefits of wearable devices in the unexpected events. It was found that current types of recommendation agents may not be

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suitable to recommend the specific wearable health devices to the users in the unexpected events. Accordingly, this study provides some solutions to improve the effectiveness of recommendation agents in recommending the specific products. It was found that context-aware recommender systems with static and dynamic contextual information and utilizing consumers' eWOM in recommendation agents can be helpful in the unexpected events for product recommendations tailored to the users' preferences.

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