Framework of Health Recommender System for COVID-19 Self-assessment and Treatments: A Case Study in Malaysia

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Summary

This paper proposes a framework for the development of the health recommender system, designed to cater COVID-19 symptoms' self-assessment and monitoring as well as to provide recommendations for self-care and medical treatments. The aim is to provide an online platform for Patient Under Investigation (PUI) and close contacts with positive COVID-19 cases in Malaysia who are under home quarantine to perform daily self-assessment in order to monitor their own symptoms' development. To achieve this, three main phases of research methods have been conducted where interviews have been done to thirty former COVID-19 patients in order to investigate the symptoms and practices conducted by the Malaysia Ministry of Health (MOH) in assessing and monitoring COVID-19 patients who were under home quarantine. From the interviews, an algorithm using user-based collaborative filtering technique with Pearson correlation coefficient similarity measure is designed to cater the self-assessment and symptoms monitoring as well as providing recommendations for self-care treatments as well as medical interventions if the symptoms worsen during the 14-days quarantine. The proposed framework will involve the development of the health recommender system for COVID-19 self-assessment and treatments using the progressive web application method with cloud database and PHP codes.

Key words:
COVID-19, home quarantine, self-assessment, collaborative filtering, Pearson correlation coefficient, health recommender system

1. Introduction

Personalized recommender systems are potentially growing in the healthcare sector as they can help to provide meaningful information about patients' health records as well as deliver recommendations for further medical treatments [1]. As Malaysia is currently facing the third wave of COVID-19 pandemic, it is essential to have such system that could help patients and health care practitioners in screening, tracing and monitoring the symptoms.

Currently, with the number of cases that have surged daily, Malaysia Ministry of Health (MOH) has encouraged the people to do their own health self-assessment based on their symptoms in order to trace and monitor symptoms' developments via announcements done through their website and social media platforms. A home assessment tool, which is a paper-based form is also being used for people under home quarantine to monitor the development of the symptoms during their 14-days quarantine [2]. This practice might be tedious and ineffective especially for initial effort to trace and screen the close contacts.

Therefore, there is a need for such system that could assist people to do home self-assessments and recommend proper medical treatments. This system will also help to gather patients' health medical records and deliver more meaningful recommendations for self-care management on how to handle and monitor COVID-19 infections.

For that reason, this paper is aimed to focus on designing the framework of a health recommender system for COVID-19 symptoms' self-assessment and treatments. To achieve this, an algorithm for the recommender engine will be designed based on the user-based collaborative filtering technique with Pearson correlation coefficient, a similarity measurement used to assess similar users' item ratings. Based on the similarity ratings derived from the Pearson correlation coefficient, the items are organized into a particular users' cluster, hence, recommendations will be provided to a new user who has similar traits of the user in that cluster [3].

The health recommender system is then designed by incorporating the progressive web application method, where it can be accessed via multi-platform such as from the web browser or as a mobile application. The objective of the health recommender system is to provide recommendations to users who are under quarantine or home surveillance for self-monitoring and health management. Through the system, the infected persons not only can perform self-assessments, but they also can monitor the developments of the symptoms overtime and contact the health care officers if the symptoms envelope into serious conditions based on the recommendations provided by the system.

2. Research Background

2.1 Health Recommender System

According to [4], recommender system can be described as a personalized program that recommends the most suitable services or products to the users based on information or historic data gathered and retrieved from various sources. These days, recommender systems have been widely implemented in e-commerce platforms such as Amazon.com, entertainment industries such as Netflix and Spotify, and even in social media platforms such as Twitter and Facebook [4]. These recommender systems can be developed using different techniques such as collaborative filtering, that captures previous users' information logs for recommendations that meet users' needs and preferences or content-based recommendation technique, which is based on the comparison between features of users and items [5]. Other than that, another technique known as knowledge-based recommendation, is built based on domain specialists or heuristic approach. Meanwhile, there is a hybrid technique, which is a mixture of different types of recommender techniques with the aim to deliver better results whilst overcome other techniques' limitations [6].

In healthcare sector, recommender system normally used by big data analytics to help in the decision-making processes regarding patients' health conditions [7]. With the emergence of the varieties of technologies such as knowledge-based recommender systems, expert decision support systems, electronic or mobile health systems, and other smart healthcare solutions, personalized health recommender system is seen rapidly gaining ground and interests in healthcare sector [7]. The objective of a personal health recommender system is mainly to support its users by recommending the most appropriate health services, diagnosing techniques, treatments, medicines and alternatives [7]. Furthermore, a personal health recommender system can be considered as medical assistance that suggests suitable health services and information on treatments to its users based on the patient's history and health status [7].

2.2 COVID-19 and Digital Health in Malaysia

The current situation of the coronavirus pandemic (COVID-19) that has already impacted nations worldwide, has put the need for digital health care solutions at the forefront with the aim to reduce the risk of cross-contamination caused by close contacts [8]. Health recommender system has been an important technology to deliver results such as recommending health diagnoses, methods, treatments and medicines based on the patient's health profile [9]. It has huge potential in helping the healthcare practitioners and community in monitoring, controlling and preventing the widespread of COVID-19.

In Malaysia health care ecosystem, such system that provides people with symptoms monitoring and tracking as well as recommending immediate medical interventions in handling COVID-19 cases remains elusive. To date, actions that have been taken by the Malaysian government in curbing the widespread of the disease include partial lockdown or movement control order (MCO), contact tracing, travel restrictions, community quarantine, utilization of official website and social media for dissemination of information, and regular press statements by the authorities [10][1]. These actions somehow have helped to flatten the curve and slow down the infections among community cases in Malaysia [12].

Nonetheless, the overwhelming number of cases have challenged the Malaysia Ministry of Health (MOH) to provide proper COVID-19 medical attentions such as screening and contact tracing that somehow has affected the front liners' physical and mental health [13]. To help in coping with the tracing and screening processes, MOH has encouraged people to use the home assessment tool, which is a paper-based form that needs to be filled in by symptomatic person [2]. The form required the infected person who is under home quarantine to list their symptoms and monitor the development of their symptoms for 14-days period [2]. This practice, however, seems to be tedious and less effective in monitoring and tracking the development of the symptoms.

Furthermore, people that exhibit COVID-19 symptoms need to have a medium or platform to track and monitor their symptoms, hence helping them in identifying any changes or deterioration of their health that need immediate medical interventions [14]. Therefore, a personalized health recommender system is needed to assist community to track and monitor their symptoms at home, provided with recommendations of medical treatments as well as channel for communication with a health care provider in order to self-manage their health.

2.3 Collaborative Filtering Recommender Technique

According to [3], collaborative filtering technique is widely being implemented in recommender systems because of its positive prediction performance. The domain independency and minimum rating dataset requirement needed for predictions has positioned collaborative filtering technique as the most successful recommender techniques compared to the other recommender techniques [3][15].

There are two main categories of collaborative filtering recommender algorithm, which are the memory-based and model-based collaborative filtering algorithms [3]. The memory-based algorithms that are also referred as neighborhood-based collaborative filtering algorithms can

be further classified into two primary types, which are the user-based and item-based collaborative filtering [16].

In user-based collaborative filtering, users who have similarities will display similar patterns of rating behavior [6]. [3] further explained that this algorithm will compute similarities between the target user A and the neighboring user, thus, the recommendations provided for user A are derived based on the ratings provided by the similar users. Meanwhile, in item-based collaborative filtering algorithms, similar items will receive similar ratings [16]. A similarity score between various items is computed, where later, the recommender system delivers recommendations to an active user [3].

2.4 Pearson Correlation Coefficient

In collaborative filtering technique, similarity measure or metric computed among users or items is determined as the key factor [15]. One of the most common similarity measures used in collaborative filtering recommender system is the Pearson correlation coefficient [15]. Previous study done by [17] has designed an algorithm using the user-based collaborative filtering algorithm with Pearson correlation coefficient similarity measurement to predict user ratings of neighboring users, thus finding the similarities among the users for meals recommendations for diabetic patients. Other study done by [5] has incorporated Pearson correlation coefficient in the development of a recommender system for IOT devices that are beneficial for users based on their preferences.

The formula for Pearson correlation coefficient used in this study is as depicted in the equation below:

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{\left[n\sum x^2 - (\sum x)^2\right]\left[n\sum y^2 - (\sum y)^2\right]}}$$

(1)

Pearson correlation will depict the degree of relationship between two factors, to which the factors are connected, and extend from +1 to – 1 [18]. A result of correlation (r), of +1 suggests that there is a strong positive direct correlation, while a -1 indicates a strong negative correlation between the two factors [18]. A zero will indicate no correlation between the factors or in other words the users have uncommon tastes [18].

For the purpose of this study, the user-based collaborative-filtering algorithm designed for the Health Recommender System will first capture users' COVID-19 symptoms that are listed by the MOH. Among the symptoms are; fever, cough, myalgia, diarrhea and ageusia, which is the loss of taste among the infected persons [2]. Later, the

recommender system will provide a list of self-care treatments together with health tips in managing and monitoring symptoms at home. Users need to rate the first recommendations for the system to have a pool of data, that later turn to be recommendations for further assessments and treatments. An extensive explanation will be given in the next section.

3. Research Methods

This section will further discuss the research methods conducted for this study that comprise of three main phases, which are; i) Investigating the symptoms of COVID-19 and MOH practices in providing home self-assessment tool for Patient Under Investigation (PUI) or close contact of COVID-19 case, ii) Designing the user-based collaborative filtering algorithm for health recommender system for COVID-19 self-assessments and treatments, and iii) Developing the framework of the health recommender system.

3.1 Investigating COVID-19 symptoms and MOH home self-assessment tool for Patient Under Investigation (PUI) or close contacts of positive COVID-19 case that are under home quarantine

MOH has provided list of guidelines for symptoms monitoring via its website that are accessible by public [2]. PUI or those who are obliged to perform self-quarantine at home because of close contacts of positive COVID-19 cases, are required to use the home assessment tool, which is a paper-based form that is used to monitor the COVID-19 symptoms for 14-days period. Figure 1 below shows part of the form needed to be used by PUI and self-quarantine persons, where they need to record the date when the infections first started and tick on the symptoms that they have experienced along the 14-days quarantine.

Figure 1. Home self assessment tool for person with symptoms and signs of respiratory tract infection used by MOH

The aim of the home assessment tool is to provide a platform for patients to self-monitor their own symptoms, where later it recommends the patients to seek for medical treatments if their symptoms have worsened over the 14-days monitoring period as depicted in Figure 2.

MONITOR YOURSELF FOR DEVELOPMENT OR WORSENINGOF SYMPTOMS

IF YOU ARECATEGORY 1: Patient Under Investigation (PUI) / Self Assessment for person with symptoms and signs of respiratory tract infection but is not warded.

If your symptoms worsen, such as:
- Difficulty in breathing; OR
- Prolonged fever more than 2 days

IMMEDIATELY contact the District Health Office at _____.

IF YOU ARE CATEGORY 2: Close contact of person infected and positive of COVID-19

If you develop any of the following symptoms such as fever/ chills / rigors / myalgia / headache / sore throat / nausea / vomit / diarrhea / fatigue / nasal congestion / running nose / cough / shortness of breath / difficulty in breathing / anosmia / ageusia

IMMEDIATELY contact the District Health Office at _____.

Figure 2. Recommendations for patients to contact medical officer if the symptoms worsen

This practice even though is helpful to the patients and medical officers; however, it has few drawbacks. From the interviews conducted with thirty former COVID-19 patients who have undergone home quarantine, 90% of them agreed that an automated system is indeed needed for the patients to perform self-monitoring instead of using pen and paper-based form, which is less effective and prone to data loss.

Besides that, with the use of a recommender system, most patients will become more aware of their symptoms development and how-to self-care or manage their symptoms at home or when is the right time for them to contact the medical officers.

3.2 Designing the user-based collaborative filtering algorithm for health recommender system for COVID-19 self-assessments and treatments

Figure 3 depicts the algorithm designed for the health recommender system using the user-based collaborating filtering technique. The algorithm will include the Pearson correlation coefficient similarity measures to compute and predict recommendations based on user's ratings.

We have selected two variables that will determine the patients' first recommendations for self-care treatments and management, which are the day the infections have started and their symptoms. Nevertheless, before the recommendations could start, firstly, the patients need to enter their users' profile that include users' background and medical history, in case they have any underlining health issues such as diabetic, high blood pressure, obesity or others as depicted in Figure 3. All these data will be stored in a database for future investigation.

Afterwards, the patients need to enter the day of the infections have started together with the symptoms as listed by MOH. From here, the system will recommend the suitable self-care treatments and management of symptoms at home for the first day the infections have occurred. As the recommendations being displayed, the patients need to rate the recommendations based on the Likert scale from 1 to 5, where scale 1 represents the least recommended self-care and treatments, while scale 5 represents the most recommended self-care and treatments.

Next, the recommender engine will grab the patients' ratings, calculate the similarities using the Pearson correlation coefficient measures, and generate a list of more detailed recommended self-care treatments and management of symptoms. The patients need to enter the data daily during the 14-days of home quarantine and rate each of the recommendation derived from the recommender system. The recommendation that will be displayed via the system will also provide notification to the patients if the symptoms have worsened along the 14-days of quarantine. This is to allow the patients to be more vigilant and aware of the symptoms' developments that may become fatal if not being treated accordingly by the medical officers.
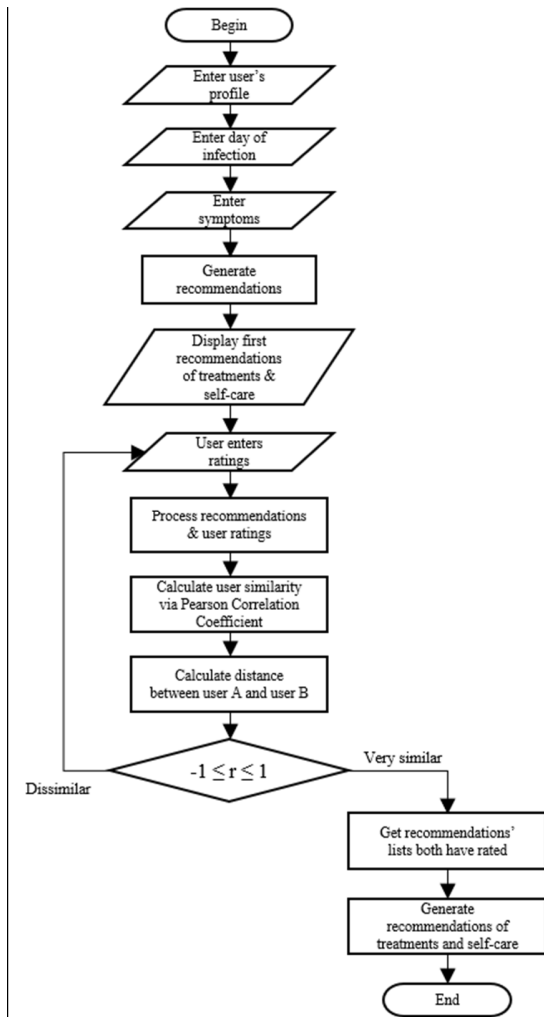
Figure 3. User-based collaborative filtering algorithm for health recommender system for COVID-19 self-assessment and treatments

3.3 Developing the framework for health recommender system for COVID-19 self-assessment and treatments

For this study, we are proposing a progressive-web application method in the development of the health recommender system framework that can be used on multi-platform, whether as a web-based system or as a mobile application. The health recommender system can be accessed by the community from dispersed locations and patients' data can be stored and secured in a cloud database. Figure 4 depicts the overall framework of the health recommender system for COVID-19 self-assessment and symptoms monitoring.
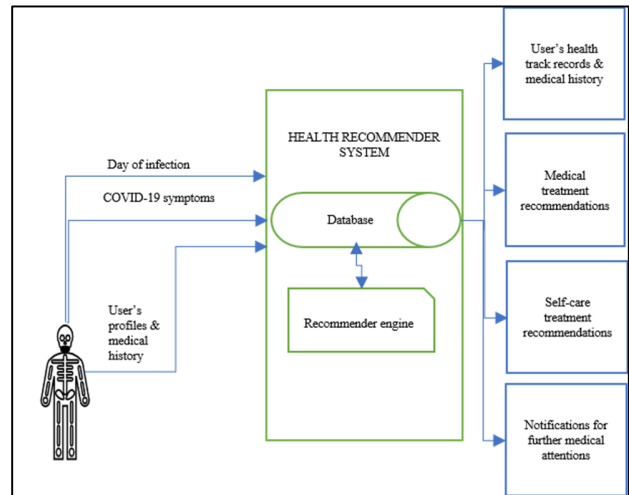
Figure 4. Proposed framework of the health recommender system for COVID-19 self-assessments and treatments

As shown in Figure 4, the patients will provide data for the system such as their user profiles and medical history, together with the day of infection and the symptoms. A cloud database will be used to store the data and scripting of the recommender engine routine will be constructed using PHP codes. The routine will compute the patients' similarity metrics as depicted in Figure 5.

Furthermore, the system will then display recommendations for medical treatments as well as home-based self-care management to the patients. If the symptoms worsen over the course of 14-days of quarantine, the system will notify the patients to seek further medical attentions.

```
function calculatePearson($userRatings, $user1, $user2)
{
    // get list of talks both have rated
    $talks = array_keys(array_intersect_key(
            $userRatings[$user1],
            $userRatings[$user2]
            ));
    $numBothHaveRated = count($talks);
    if ($numBothHaveRated === 0)
    {
        $pearson = 0;
    }
    else
    {
        $sumOfRatingsUser1 = 0;
        $sumOfSquareOfRatingsUser1 = 0;
        $sumOfRatingsUser2 = 0;
        $sumOfSquareOfRatingsUser2 = 0;
        $sumOfProducts = 0;

        foreach ($talks as $talkId)
        {
            $sumOfRatingsUser1 += $userRatings[$user1][$talkId];
            $sumOfSquareOfRatingsUser1 += pow($userRatings[$user1][$talkId], 2);
            $sumOfRatingsUser2 += $userRatings[$user2][$talkId];
            $sumOfSquareOfRatingsUser2 += pow($userRatings[$user2][$talkId], 2);
            $sumOfProducts += $userRatings[$user1][$talkId] * $userRatings[$user2][$talkId];
        }
        // calculate pearson
        $numerator = $sumOfProducts - ($sumOfRatingsUser1 * $sumOfRatingsUser2 / $numBothHaveRated);
        $denominator = sqrt(
                ($sumOfSquareOfRatingsUser1 - pow($sumOfRatingsUser1, 2) / $numBothHaveRated)
              * ($sumOfSquareOfRatingsUser2 - pow($sumOfRatingsUser2, 2) / $numBothHaveRated)
                );
        if ($denominator == 0)
        {
            $pearson = 0;
        }
        else
        {
            $pearson = $numerator / $denominator;
        }
    }

    return $pearson;
}
```

Figure 5. Recommender engine routine coded in PHP to compute patients' similarity based on Pearson correlation coefficient similarity measure.

3. Conclusion

As the health recommender system for self-assessment and treatments for COVID-19 patients is still under development, this paper has given an overview of the proposed framework of the health recommender system with user-based collaborative filtering technique. Via this system, the patients will provide ratings to each of the recommendation daily and then, the ratings are being computed using the Pearson correlation coefficient similarity measures that are coded using PHP scripts in order to predict similarities between patients. The recommendations provided by this system involve recommendations for self-care treatments, medical treatments as well as notification as an alert system for further medical interventions.

The health recommender system for COVID-19 can be seen as a potential medium to help Malaysian government in coping with the increasing number of daily cases, where assessment and monitoring of patients' symptoms can be done daily at home in a hassle-free manner. It is hoped that the system, when it is fully developed and tested can also help the patients of COVID-19 who must be home quarantined, monitor their own symptoms diligently and becoming more aware of COVID-19 self-assessment and treatments.

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