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DECISION MAKING MODEL FOR DETECTING INFECTED PEOPLE WITH COVID-19

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Abstract: The detection of people that are infected with COVID-19 is critical issue due to the high variance of appearing the symptoms between them. Therefore, different medical tests are adopted to detect the patients, such as Polymerase Chain Reaction (PCR) and SARS-CoV-2 Antibodies. In order to produce a model for detecting the infected people, the decision-making techniques can be utilized. In this paper, the decision tree technique based Decisive Decision Tree (DDT) model is considered to propose an optimized decision-making approach for detecting the infected people with negative PCR test results using SARS-CoV-2 antibodies and Complete Blood Count (CBC) test. Moreover, the fever and cough symptoms have been adopted as well to improve the design of decision tree, in which the precision of decision is increased as well. The proposed DDT model provide three decision classes of Infected (I), Not Infected (NI), and Suspected (S) based on the considered parameters. The proposed approach is tested over different patients' samples in off and real-time simulation, and the obtained results show a satisfactory decision class accuracy ratio that varies from 95% to 100%.

Keywords: Operations research, decision making, decision tree, COVID-19 tests.

MSC: 90B50.

1. INTRODUCTION

The modern technologies that are utilized in the information systems leads to produce efficient detection approaches for different diseases. These approaches reduce the need for experts, who might be busy in more complicated cases, in diagnosing the related diseases. The adopted datasets for these systems can be laboratory test results, and medical images that help even experts in diagnosing them in early stages [1]-[5].

At the last months of the year 2019, the Coronavirus pandemic has been appeared in a sever way to affect people throughout the transportation in air. The number of infected people is large enough to cause a crowd in the health institutes. Therefore, the need for smart system that can detect the infected people without seeing the experts is increased sharply. The operations research approach is adopted by many researchers to build COVID-19 detection systems, including decision tree [6]-[8].

The decision making techniques have been widely used in COVID-19 in different criteria. It is well known that the decision making is a part of the operations research area that manages numerous fields of controlling the related aspects. These decisions include managing the human resource, data, patient's care, controlling the crisis, etc. The decisions in disasters and crisis become more complicated due to the number of requirements, thus the automatic decision algorithms are highly recommended. The automatic decisions are structured based on real aspects of the considered field to be more accurate [9].

In the field of health, different types of automatic decision making systems are presented to cover the huge requirements of managing the patients particularly in emergency cases, such as COVID-19. In COVID-19, the physicians suffer from the load of COVID-19 diagnosing and managing the care process. The same confusions are appeared with the health staff in centers. Therefore, the researchers have motivated toward finding the solutions for this problem by introducing systems that adopt the computer based software platforms for diagnosing the COVID-19. These software platforms consider the operations research decision making techniques. One of the most important decision-making techniques is decision tree that are mostly used in diagnosing COVID-19 [10]-[11].

As mentioned above, the researchers have a big motivation in producing an automatic COVID-19 diagnosing system based on decision making, However, these systems suffered from the accuracy of diagnosing due to the less information required for preceding the decision making. In this paper, the operations research decision making approach is considered for producing a model that detects the infected people with Coronavirus using the proposed Decisive Decision Tree (DDT) based decision tree optimization method. The proposed method adopts the SARS-CoV-2 antibodies test and the CBC test parameters as well as fever and cough symptoms for negative PCR test to provide the right decision either a person is infected or not, or even suspected cases. Different case studies for groups of people's tests have been employed in testing the proposed method and the results proves the efficiency of detection that reaches 100%.

2. RELATED WORK

Different research works have been introduced around the world to provide the health section with a smart detection system for Coronavirus infections. In [12], the authors produced a study that showed the effects of using operations research in decision making systems. It proved that the management systems with decision criteria could be improved using the concepts operations research and the taken decision is almost accrued. Moreover, the development of operations research decision making in the health sector from 1952 to 2016 was studies and analyzed in [13]. The development is allocated in the concepts and techniques that were used in the literature, in which the diagnosing systems were improved in terms of detection accuracy and speed. The authors of [14] discussed the utilizing of optimization of decision tree and linear programming in managing the gained profits and production scheduling in factories. They improved the profit ratio by 25% under the condition of production guarantee by 100%. This helped the factories and companies in managing the producing and marketing of their products in optimized way.

In [15], the decision making methods were studies well to show their superior in providing the best solution to the complex and multi-objectives problems. The decision makers always were being in confusion state, when the multi-objective problem is produced. Therefore, the employing of the decision making based operations research, can help in efficient state. In addition, a developed decision tree model was introduced in [16] to facilitate the sustainable development assessment in different companies and factories. The developed model optimally solved the complex problems of managing the production and planning in five criteria that were related to gaining profits and controlling the inventory.

In [17], am evaluation of the provided health serves for COVID-19 infection in Somalia country. This country suffered from fighting and comes out with a deep lack in health services. It appeared that the circumstances in this country had bad effects in responding the infection, which leads to the widely distribution that affected most of age gaps of people, but particularly the old ones. In addition, the author of [18] studied the effects of wrong decision that have been taken in time of COVID-19 on the providing fast response to patients. Different factors had been recorded including failure of searching, information, treatments and so on. Based on these failures, they proposed a platform for providing an optimized decision to be close as much as possible to the real diagnosing. In [19], the authors intended to find out the aspect parameters that can affect people who select self-protection against the COVID-19 infection. They adopted the risk home ostasis method in allocating the behavior of the individuals across the COVID-19 period as well as the action decision model to make the right decision in protection. From this study, the women were the most protective samples against COVID-19, while the young ages of 18-30 years old were less concerned.

At the other side, the authors of [20] introduced a deep-learning method in detection the infected people with COVID-19 based on X-ray and CT-scan images of lunges. While in [21]-[24], the SARS-CoV-2 antibodies were adopted in detecting the infected people using deep-learning model as an intelligent system, the infection ratio and positive likelihood ratio. Most of the tested samples were returned with accuracy ratio of 99-100%. Moreover, the serological diagnosing test of Coronavirus was adopted as a testing kit in [25]-[33] as well as the fast rapid test kits. The SARS-CoV-2 antibodies were analyzed and produced as main indicators for detecting the COVID-19.

3. PROPOSED DECISION MAKING APPROEACH

In this section, the proposed decision making system for detecting infected people with COVID-19 is explained. As mentioned before, the decision tree model has been considered to find out the optimized decision regarding three cases of infected, disinfected, and suspected of people depending on the employed parameters. The DDT model is adopted in designing the proposed decision making tree. Moreover, the adopted parameters are listed in Table 1 with their normal ranges. This section is divided into two subsections for easing the reading flow.

2.1. Proposed Decision Tree Design

The DDT model is considered in designing the decision tree that produces three classes of Infected (I), Not Infected (NI), and Suspected (S). The root node of the tree is the PCR test and the parameters, shown in Table 1, are adopted to be the child nodes. Each node has its own threshold that is explained in Table 1 with two decisions; either Positive (P), or Negative (N).

Table 1: Parameters illustration

No	Parameter	Thresholds
1	PCR	Negative=0, Positive=1
2	SARS-COV-2 antibodies	Negative=0, Positive=1
3	WBC	4-11 x10^3/uL
4	Lym%	20% - 50%
5	Fever	≤37 c^o
	Cough	Negative=0, Positive=1

The DDT model is built by re-expressing the problem idea into attributes, and then find out the relations between them and the specified classes. According to the evaluated relations, the attributes are weighted to represent the priority and effect of them on the obtained decision. Thus, the training of the designed trees using a satisfactory dataset can improve the optimality of taking the right decisions. The significant degree with the target class, D_t, can be evaluated based on the frequency of occurring success classes (F_s) and frequency of occurring the fail classes (F_f) as [34]:

$$D_t = \frac{F_s - F_f}{F_s + F_f} \quad (1)$$

The evaluated decisive value (degree) plays a main role in weighting the features of the training phase and confirm the relation with the target classes. It is computed for the considered parameters of health test of patients to get the suitable weight and relation between each one and the target class. This is the main motivation in using the DDT in this paper, as the detection of the infected cases is based on the considered features that affect on the diagnosing decision in different levels depending on the assigned weight of each. Moreover, the DDT provide the proposed approach high speed in producing the decision with acceptable successful ratio.

Figure 1 explains the proposed DDT that considers the possible probabilities of infection occurring depending on the employed parameters. The working steps of the DDT model are:

1. In case that the PCR test is come with positive, the tree decides that this person is infected and the classified as I class.
2. If the PCR test is negative, the tree considers the next important parameter, which is SARS-COV-2 antibodies. In case this parameter is positive, the tree classifies the patient with I class, otherwise, the tree adopts the next parameters, fever.
3. The node fever goes with two options, in case of negative and positive, tree selects the next parameters of cough with two different options for each.
4. The negative fever with negative cough means the tree gives the NI class, while the negative fever with positive cough makes the tree to consider the next *parameter of WBC.
5. The class S is the result of negative fever, positive cough and WBC, while the NI class comes from negative fever, positive cough and negative WBC.
6. Positive fever, cough WBC, and Lym% leads to get the class I, while the class S is the result of positive fever, cough and WBC with negative Lym%.

7. Class I is obtained from positive fever, and cough, negative WBC with positive Lym%. Moreover, positive fever, and cough with negative WBC and Lym% provide the class of S.
8. The class I can be achieved from positive fever, WBC and Lym% with negative cough, while the class S is obtained by positive fever and WBC with negative cough and Lym%. The S class is also the result of positive fever, negative cough and WBC.

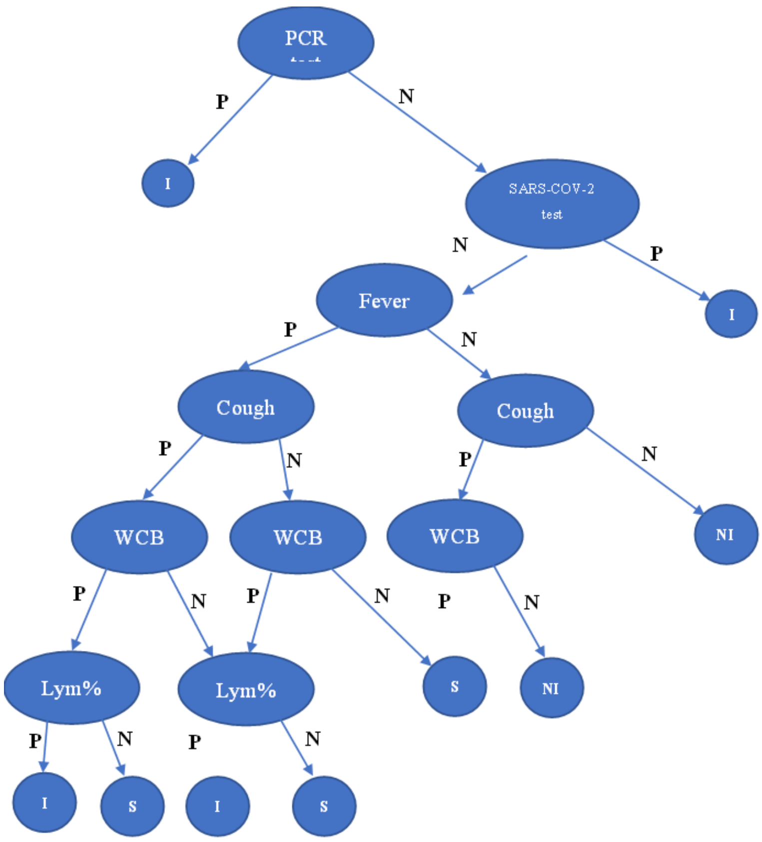

Figure 1: Proposed DDT model

2.2. Proposed Decision-Making Algorithm

In order to declare the working steps of the adopted DDT model, an algorithm is proposed for applying this model in efficient way, as shown in Figure 2. In this figure, the proposed algorithm is formulated as a flowchart model that explains the working procedure of DDT and the preprocessing steps as:

1. The proposed algorithm starts by formulating the included parameters.
2. The required programming functions are prepared for applying the proposed DDT.

3. Collecting the parameters and then check the validity of them for preceding the DDT.
4. Applying the proposed DDT to get the suitable class of I, NI, and S.
5. Assessing the achieved results in terms of classification the patient cases.
6. In case the results are valid, they are exported as decision classes.

The prepared programming functions are built using Matlab environment to perform the proposed DDT model and collecting the parameters. These functions use the adopted parameters as input and the decision of the suitable class is the output. In addition, the parameters are collected after applying the formulation by changing the definition and types of data to be sure that all parameters are suitable for performing the proposed DDT model.

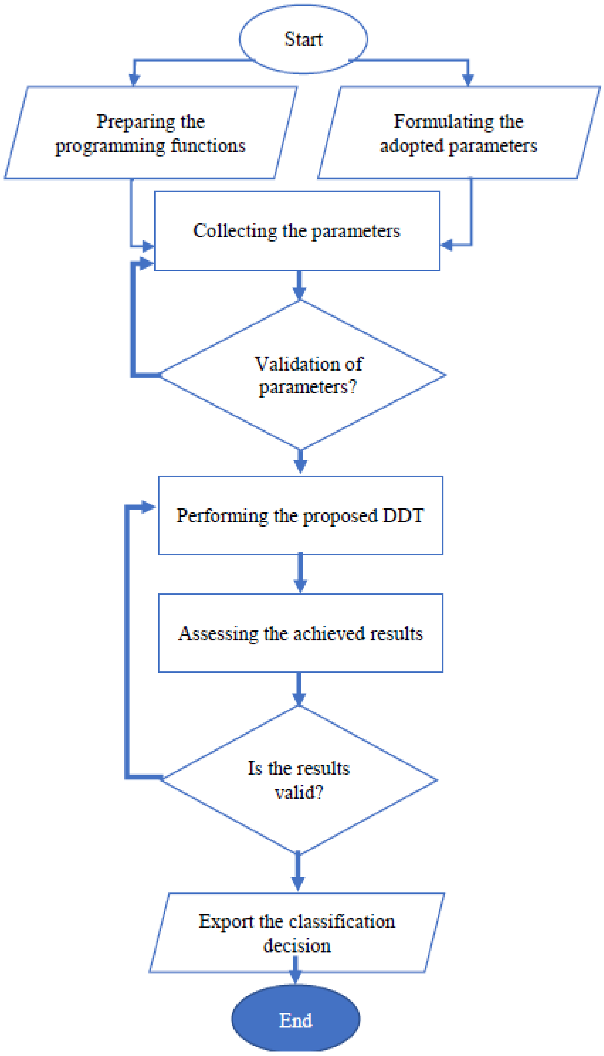

Figure 2: Proposed decision making algorithm

3. COLLECTED PATIENT'S SAMPLES

The samples of 1000 patient are collected from different health institutes that covers different case studies in terms of parameters ranges and age range. All cases have been come up with negative PCR test to improve that this test cannot give the right decision of infection by COVID-19 in high precision. The samples are grouped in bands depending on the correlated parameters values as explained in Table 2. The patients within each band shares the same test results (parameters).

Table 2: Bands of patients' samples

Band	No. of samples	PCR test	SARS-COV-2	WBC	Lym%	Fever	Cough
First	257	Negative	Positive	Over threshold	Down threshold	Over threshold	Positive
Second	225	Negative	Positive	Over threshold	Down threshold	Within thresholds	Negative
Third	204	Negative	Positive	Within thresholds	Down threshold	Within thresholds	Negative
Fourth	157	Negative	Positive	Within thresholds	Within thresholds	Within thresholds	Positive
Fifth	61	Negative	Positive	Within thresholds	Within thresholds	Within thresholds	Negative
Sixth	53	Negative	Negative	Within thresholds	Within thresholds	Within thresholds	Negative
Seventh	43	Negative	Negative	Over threshold	Over threshold	Over threshold	Negative

4. RESULTS AND DISCUSSION

The proposed DDT and related algorithm are tested over the considered samples of patients, shown in Table 2. Matlab software environment is adopted for implementing the proposed algorithm, in which the DDT is embedded. The samples are considered as dataset for assessing the proposed DDT for each band individually. Therefore, the obtained results including the accuracy and decision class are explained for each band.

Table 3 illustrates the results of decision class from the DDT and the accuracy ratio of getting the right decision. It is well shown that the accuracy ratio is varied dependently on the related sample bands. Thus, the obtained decision class is allocated between I, NI, and S classes, while the accuracy reaches 99% for the first band as I class, 99% for the sixth band as class NI, and 91% for S class for seventh band.

Table 3: Decision classes for bands of sample

Band	Decision Class	Accuracy Ratio
First	I	99%
Second	I	98%
Third	I	97.8%
Fourth	I	97%
Fifth	I	97%
Sixth	NI	99%
Seventh	S	91%

The accuracy ratio is considered as important factor in assessing the proposed DDT model and can be computed based on the number of right classification (N_R), total included cases for each band (N_T) as:

$$Accuracy\ Ratio = 100 \times \frac{N_R}{N_T} \quad (2)$$

At the other hand, the correct classification in real life is the responsibility of experts (doctors) based on the offered samples. The proposed model can solve this problem of loading the experts in real-time systems. The information systems suffer from some wrong results, yet within the accepted error ratio. The wrong decision of classification is the result of considering the samples with parameters values varies between the thresholds.

A total of 100 samples are tested in real-time status by the proposed DDT model supported with the proposed algorithm. Table 4 explains the results of decision class and accuracy for the 100 samples. These samples are come with negative PCR test to show the strongest of COVID-19 detection for patients, who are ill with negative PCR test.

The results of Table 4 explain that the accuracy ratios of getting the right decision class are varied for different sample bands. The considered bands are First, Fourth, Sixth and Seventh to cover the most possible parameters of samples, particularly the critical cases that have errors, to test the proposed DDT model in efficient way.

Table 4: Results of 100 real-time samples

Band	**No. of patients**	**PCR**	**SARS-COV-2**	**WBC**	**Lym%**	**Fever**	**Cough**	**Decision Class**	**Accuracy Ratio**
First	10	Negative	Positive	Over threshold	Down threshold	Over threshold	Positive	I	100%
Fourth	20	Negative	Positive	Within thresholds	Within thresholds	Within thresholds	Positive	I	100%
Sixth	30	Negative	Negative	Within thresholds	Within thresholds	Within thresholds	Negative	NI	96.6%
Seventh	40	Negative	Negative	Over threshold	Over threshold	Over threshold	Negative	S	95%

In order to check the suitability of the proposed DDT in real-time systems, the execution time for the proposed algorithm is listed in Table 5 based on the bands, illustrated in Table 4. It can be seen that the seventh band consumes more time that other bands to obtain the suitable class of 40 patients. While the sixth band needs less time than the seventh band for 30 patients and this is due to the decreasing in the number of patients. In this procedure, the first band with 10 patients requires the lest time for producing the decided class.

Table 5: Execution time evaluation

No	**Band**	**Execution time (MS)**
1	First	136
2	Fourth	260
3	Sixth	327
4	Seventh	374

Depending on the obtained results explained above, the proposed DDT model and related algorithm prove their ability in detecting the infected people with COVID-19 with high accuracy as an operations research decision making process. The proposed DDT model can solve the loading problem on experts, particularly in the days of emergency cases that cause really management problem at hospitals. This model can be implemented in hospital system as well as mobile applications that can offer the detection service at anywhere and anytime in early diagnosing time. The early diagnosing can guarantee the recovery of patients in acceptable period of time and prevent the distribution of infections around the world.

5. CONCLUSIONS

The operations research as a decision making was utilized to design a model for detecting the patients with COVID-19. The DDT based decision tree was adopted as a decision making method to optimize the selection of the right class of infection. Three classes were considered in the proposed DDT model to be Infected (I), Not Infected (NI), and Suspected (S). The DDT model decided the class of patient sample based on the measured parameters of PCR, SARS-COV-2 antibodies, and CBC tests, as well as the fever and cough symptoms. These parameters were distributed in the designed DDT between the root (father) node and child nodes that had branches with positive and negative choices. A 1000 patient samples were considered in testing the proposed DDT and related algorithm in off-time performance, while a 100 real-time samples were adopted to show the performance of the proposed methods in different case studies. The obtained results showed the high accuracy ratio of decision classification for off and real-time simulations. The proposed model could reduce the load on hospitals and experts as well as offering home testing ability for patients. The operations research methods helped the information systems to cover most of the case studies. The proposed approach is limited with the number of considered parameters (features) to maximum of ten. After ten features, other optimization method can be used with the AI combination to get more reliable model. As a suggestion for future work, the deep-learning models can be used for increasing the accuracy of detecting the patients with COVID-19 after offering more features from medical tests.

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