Quantum associative memory for the diagnosis of some tropical diseases

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Abstract

In this paper we present a model of Quantum Associative Memory which can be a helpful tool for physicians without experience or laboratory facilities, for the diagnosis of four tropical diseases (malaria, typhoid fever, yellow fever and dengue) which have similar symptoms. The memory can distinguish single infection from multi-infection. The algorithm used for Quantum Associative Memory is an improve model of original algorithm made by Ventura for Quantum Associative Memory. From the simulation results given, it appears that the efficiency of recognition is good when a particular symptom of a disease with a similar symptoms are inserted.

1 Introduction

Diagnosis is the identification of abnormal condition that afflicts a specific patient, based on manifested clinical data or lesions. If the final diagnosis agrees with a disease that afflicts a patient, the diagnostic process is correct; otherwise, a misdiagnosis occurred. Medical diagnosis is a categorization task that allows physicians to make prediction about features of clinical situations and to determine appropriate course of action. It involves a complex decision process that involves a lot of vagueness and uncertainty management, especially when the disease has multiple symptoms.

Artificial neural networks provide a powerful tool to help physicians avoiding misdiagnosis by analyzing, modelling and making sense of complex clinical data across a broad range of medical applications. Most of medical applications of artificial neural networks are classification problems; that is, the task is on the basis of the measured features to assign the patient to one of a small set of classes [1].

Malaria is most world parasitic disease. 40% of the world’s population are concerned, especially those of tropical regions. In Cameroon it is a public health problem because all the population is exposed to the disease. To diagnose malaria, the World Health Organization (WHO) [2] recommends the use of rapid diagnostic testing. But these tools need some conservations facilities which are difficult to find in rural and semi-urban regions in developing countries. In fact it is crucial to maintain the frozen chain because the storage over some temperatures and high humidity affect their sensibility and efficiency. So the most widely used technique for determining the development stage of the malaria disease is visual microscopical evaluation of Giemsa stained blood smears. However, this is a routine and time-consuming task and requires a trained operator. But, most of the time there is a misdiagnosis because of confusion between symptoms of malaria and symptoms of other tropical diseases like typhoid fever, yellow fever and dengue, or the inexperience of the physicians.

For the diagnosis of four tropical diseases (malaria, typhoid fever, yellow fever and dengue) which have similar symptoms, the purpose the Quantum Associative Memory (QAM) proposed here is to (i) act as an advisory tool to novice users, specifically senior nurses in rural health centers with limited or no physicians; (ii) act as a decision support tool for medical diagnosis for physicians in under staffed health centers; (iii) provide an alternative way to reach a reasonable tentative diagnosis, and hence early commencement of clinical management of patients in the absence of laboratory facilities in many rural and semi-urban health centers.

Some computer-assisted tools in the case of tropical diseases are already built and some of them use artificial neural networks, but they are only specialized for malaria [3, 4, 5, 6, 7]. The use of artificial neural networks is
motivated by the fact that they can capture domain knowledge from example and have good generalization. Our model, which generalize the work of Agarkar and Ghathol [8] that use the FFANN for the diagnosis of malaria, typhoid fever and dengue, will be further extended to a wide range of tropical diseases.

The paper is structured as follows. Section 2 provides a brief description of the symptoms of each disease, described in detail in Appendix A. In Section 3, foundations of our Quantum Associative Memory are presented. Section 4 is devoted to simulations and results. Finally, we conclude with an outlook of possible future directions.

2 Short description of the symptoms of the diseases [9, 10]

We briefly give here the symptoms of each disease, described in detail in Appendix A.

Malaria is caused by protozoan parasites of the genus plasmodium. Four species infect humans by entering the bloodstream: P. vivax, P. ovale, P. malariae and P. falciparum which affects a greater proportion of the red blood cells than the others and is most serious. The parasite is generally transmitted from one human to another by the bite of infected anopheles mosquitoes.

Typhoid fever, also known as salmonellosis, is a bacterial disease caused by salmonella typhi. Dirt is the main cause of transmission of the disease. Contaminated food and water are the principal vectors.

Yellow fever is caused by flavivirus. The virus is transmitted by the bite of a mosquito (Aedes aegypti). The virus cause deterioration of the liver.

Dengue is caused by dengue virus. The virus is transmitted by the bite of mosquito (Aedes aegypti and Aedes albopictus). The WHO has classified dengue as one of the neglected tropical diseases and report the resurgence of the disease [11].

3 Method

3.1 Algorithm for data search

The algorithm that we use for retrieving was originally proposed by Ezhov and Ventura [12] as quantum associative memory with distributed queries. In the Ref. [13] we improved it by making some modifications. The resulting algorithm is given by Algorithm 1.

Algorithm 1 Improve Quantum Associative Memory with distributed query

1: |00...0⟩ ≡ |0⟩; {Initialize the register}
2: |Ψ⟩ = A |0⟩ = \frac{1}{\sqrt{N - m}} \sum_{x \in M} |x⟩; {Learn the patterns using exclusion approach which can be made by the Binary Superposed Quantum Decision Diagram (BSQDD) proposed by Rosenbaum (see [14] for detail)}
3: Apply the operator oracle O to the register;
4: Apply the operator diffusion D to the register;
5: Apply operator I_M to the register;
6: Apply the operator diffusion D to the register;
7: repeat
8: Apply the operator oracle O to the register;
9: Apply the operator diffusion D to the register;
10: i = i + 1;
11: until i > Λ − 2
12: Observe the system.

It should be noted that to get original Ezhov and Ventura’s algorithm [12] lines 3 to 6 must be omitted and in line 11 i > Λ.

The model uses the exclusion learning approach in which the system is in the superposition of all the possible states, except the patterns states. If M is the set of patterns and m the number of patterns of length n,

|Ψ⟩ = \frac{1}{\sqrt{N - m}} \sum_{x \in M} |x⟩, N = 2^n. \quad (1)

In other words, the exclusion approach for the learning pattern included each point not in M with nonzero coefficient while those points in M have zero coefficients.
The distributed query is in the following superposed states

\[ |Req_p^p⟩ = \sum_{x=0}^{N-1} Req_x^p |x⟩, \tag{2} \]

where \( Req_x^p \) obey to binomial distribution

\[ \|Req_p^p\|^2 = a_{H(p,x)}(1 - a_{H(p,x)})^n - d_{H(p,x)}. \tag{3} \]

In equation (3)

- \( p \) marks the state \(|p⟩\) which is referred as the query center;
- \( 0 < a < \frac{1}{2} \) is an arbitrary value that regulates the width of the distribution;
- the Hamming distance \( d_{H(p,x)} = |p - x| \) between \(|x⟩\) and \(|p⟩\) is an important tool which gives the correlation between input and output;
- the amplitudes are such that \( \sum_x \|Req_x^p\|^2 = 1. \)

In the Algorithm 1,

- \( O \) is the operator oracle which inverts the phase of the query state \(|Req_p⟩\),

\[ O = I - (1 - e^{iπ}) |Req_p⟩⟨Req_p|, \tag{4} \]

\[ O : a_x \mapsto a_x - 2Req_x^p \left( \sum_{x=0}^{2^n-1} (Req_x^p)^*a_x \right), \tag{5} \]

where \( a_x \) is the probability amplitude of the state \(|x⟩\).

- \( D \) is the operator diffusion which inverts the probability amplitude of the states of \(|Ψ⟩\) over their average amplitude and for the others over the value 0.

\[ D = (1 - e^{iπ}) |Ψ⟩⟨Ψ| - I, \tag{6} \]

\[ D : a_x \mapsto 2m_x \left( \sum_{x=0}^{N-1} m_x^*a_x \right) - a_x, \tag{7} \]

where \( m_x \) is the probability amplitude of a state of \(|Ψ⟩\).

- \( Λ \) is the number of iterations that yields the maximal value of amplitudes, which must be as far as possible nearest to an integer,

\[ Λ = T \left( \frac{1}{4} + \alpha \right), T = \frac{2π}{ω}, \alpha \in \mathbb{N}, \tag{8} \]

with the Grover’s frequency

\[ ω = 2 \arcsin B, B = \frac{1}{\sqrt{N - \sum_{x=0, x \notin M}^{N-1} Req_x^p}}. \tag{9} \]

Two cases we be will considered for the operator \( I_M \):

**QAM-C1:** \( I_M \) inverts only the phase of the memory patterns states as in the Ventura’s model,

\[ I_M = I - (1 - e^{iπ}) |φ⟩⟨φ|, |φ⟩⟨φ| = \sum_{x∈M} |x⟩⟨x|, \tag{10} \]

\[ I_M : a_x \mapsto \begin{cases} -a_x & \text{if } |x⟩ \in M \\ a_x & \text{if not.} \end{cases} \tag{11} \]

\( ∀x ∈ M \), the Grover operator acts as

\[ DI_M |φ⟩ = (2 |Ψ⟩⟨Ψ| - 1 + 2 |φ⟩⟨φ|) |φ⟩ = 2 |Ψ⟩⟨Ψ| - |φ⟩ + 2 |φ⟩⟨φ| = |φ⟩. \tag{12} \]
QAM-C2: $I_M$ is formally identical to the operator oracle $O$ of Eq. (5),

$$I_M : a_x \mapsto a_x - 2REQ_x \left( \sum_{x=0}^{N-1} (REQ_x)^* a_x \right),$$

with

$$\|REQ_x\|^2 = \frac{1}{k} \sum_p \alpha_b^{d_H(b,x)} (1 - \alpha_b)^{n-d_H(b,x)},$$

where we consider that the distribution has $k$ centers and $0 < \alpha_b < \frac{1}{2}$ is an arbitrary value that regulates the width distribution around the center $b$. But in this paper, we will consider that

$$\|REQ_x\|^2 = \frac{1}{m} \sum_{b \in M} \alpha_b^{d_H(b,x)} (1 - \alpha_b)^{n-d_H(b,x)},$$

where $m$ is the number of patterns for the learning, $b$ is an item of the set $M$ of patterns, and we choose the case where $a' = a_b$ is the same for all the patterns.

### 3.2 Database

Our database contains symptoms of four tropical diseases: malaria, typhoid fever, dengue and yellow fever. There is 23 symptoms for malaria, 16 for typhoid fever and dengue and 10 for yellow fever. According to the fact that some symptoms are common to different diseases, not only the four, like fever and headache for example, our database is reduced to 47 symptoms. Each symptom is labelled with a number, from 0 to 46, in its binary form, so we need 6 qubits for the computation. Furthermore, we need 4 qubits to label the ten groups of diseases presented by Table 1. There is one group per individual disease (‘N°1-4); three groups corresponding to common symptoms to malaria and typhoid fever, or dengue, or yellow fever (‘N°5-7); one group corresponding to common symptoms to yellow fever and dengue (‘N°8); one group corresponding to common symptoms to malaria, yellow fever and dengue (‘N°9); and finally one group corresponding to common symptoms to each of the four diseases and that can be found in other diseases as headache, fever and vomiting (‘N°10). It appears that we need a register which contains $n = 10$ qubits, 6 for symptoms and 4 for diseases, all labelled as mentioned above. The other possibilities are pointed to be other diseases and symptoms in our model.

| N° | Group of diseases by symptoms | Label |
|----|-------------------------------|-------|
| 1  | Malaria                       | 0001  |
| 2  | Typhoid fever                 | 0010  |
| 3  | Yellow fever                  | 0100  |
| 4  | Dengue                        | 1000  |
| 5  | Malaria + Typhoid fever       | 0011  |
| 6  | Malaria + Dengu              | 0101  |
| 7  | Malaria + Yellow fever        | 0110  |
| 8  | Yellow fever + Dengue         | 1010  |
| 9  | Malaria + Yellow fever + Dengue| 1101  |
| 10 | Other diseases                | 0000  |

Table 1: Groups of diseases by symptoms and their labels in binary form. The hamming distance between the label of two groups of diseases is equal to one when the symptoms are common to these two groups of diseases and is equal to two otherwise. The group N°10 or Other groups of diseases is devoted to symptoms that are common to each of the four diseases and that can also occur in other groups of diseases which are not mentioned here.

As we want the Quantum Associative Memory to give as output a disease that corresponds to symptoms give as inputs, some modifications must be done on the operators of the Algorithm 1. Concretely, we want the operator $O$ and the operator $I_M$ to act on the subspace of diseases (last 4 qubits): $I_0 \otimes O_4 = O$; while the operator $D$ acts on the subspace of symptoms (first 6 qubits): $D_6 \otimes I_4 = D$. The Algorithm 1 must be rewriting as the Algorithm 2, where $I$ is the identity operator. The determination of the number of iterations is still the same as mentioned above, but the distributed query must be transposed from his subspace to the global Hilbert’s space as

$$|Req^p\rangle = \frac{1}{8} \sum_{y=0}^{15} \sum_{x=0}^{63} Req^p_y |x\rangle \otimes |y\rangle,$$

where $p$ takes one of decimal values of the label gives on the Table 1.
Algorithm 2 Improve Quantum Associative Memory with distributed query for diagnosis #1

1: \(|0102\ldots0_n\rangle \equiv |\bar{0}\rangle\); \{Initialize the register\}
2: \(|\Psi\rangle = A |\bar{0}\rangle = \frac{1}{\sqrt{N}} \sum_{x \in M} |x\rangle\); \{Learn the patterns using exclusion approach which can be made by the Binary Superposed Quantum Decision Diagram (BSQDD) proposed by Rosenbaum (see [14] for detail)\}
3: Apply the operator oracle \(I_6 \otimes O_4 = O\) to the register;
4: Apply the operator diffusion \(D_6 \otimes I_4 = D\) to the register;
5: Apply operator \(I_6 \otimes I_M = I_M\) to the register;
6: Apply the operator diffusion \(D_6 \otimes I_4 = D\) to the register;
7: repeat
8: Apply the operator oracle \(I_6 \otimes O_4 = O\) to the register;
9: Apply the operator diffusion \(D_6 \otimes I_4 = D\) to the register;
10: \(i = i + 1\);
11: until \(i > \Lambda - 2\)
12: Observe the system.

4 Simulations and results

For the simulations we choose four symptoms that we know the corresponding disease, i.e., symptoms that occur only when a patient suffers from the corresponding disease. As for QAM-C2 method, best results appear when \(a'\) is close to 0.5, we take here 0.4999. The symptoms and an appropriate scheme determine the center of the query. For example, if we introduce some symptoms of malaria and typhoid fever, the center of the query will be \(|0011\rangle\). We give the ratio \(P_c/P_w\) which is the recognition efficiency of the Quantum Associative Memories, where \(P_c\) and \(P_w\) are probabilities of correct and incorrect recognition. More is this ratio, better is the recognition.

1. Malaria: Table 2 and Figure 1 give the relevant parameters of each method.

| QAM   | \(A\) | \(P_c/P_w\) Measure on the 6 first qubits | \(P_c/P_w\) Measure on the 4 last qubits |
|-------|-------|---------------------------------|---------------------------------|
| Ezhov’s | 1     | 0.1767                          | 1.5823                          |
| C1     | 2     | 0.1873                          | 1.9710                          |
| C2     | 2     | 0.1841                          | 1.6900                          |

Table 2: Relevant parameters of Ezhov’s, QAM-C1 and QAM-C2 methods in case of the diagnosis of malaria.

2. Typhoid fever or dengue: Table 3 and Figure 2 give the relevant parameters of each method for the diagnosis of typhoid fever. In case of the diagnosis of dengue, same results occur. The reason is the number of symptoms of each disease which is equal for both.

| QAM   | \(A\) | \(P_c/P_w\) Measure on the 6 first qubits | \(P_c/P_w\) Measure on the 4 last qubits |
|-------|-------|---------------------------------|---------------------------------|
| Ezhov’s | 11    | 0.1374                          | 1.2967                          |
| C1     | 14    | 0.1374                          | 1.2967                          |
| C2     | 12    | 0.1611                          | 1.4125                          |

Table 3: Relevant parameters of Ezhov’s, QAM-C1 and QAM-C2 methods in case of the diagnosis of typhoid fever (or dengue).

3. Yellow fever: in this case we choose only two symptoms of the disease because it has the lower number of symptoms. Here Table 4 and Figure 3 give the relevant parameters of each method.

As we see on each figure, due by the hamming distance, the Quantum Associative Memory can collapse to the states of mark for multi-infection. But the use of the QAM-C2 method seem to be the best in terms of probabilities and iterations for single disease retrieving. The Quantum Associative Memory is also built to identify a disease with the lowest (one) or the highest (all) number of particular symptoms of this disease. But when we introduce one or more of the three common symptoms, the probability that the Quantum Associative Memory collapses to other disease is still important. Table 5 shows it when the same symptoms previously introduce are completed with the common symptoms in case of malaria when measure was done on last four qubits.
(a) Ezhov’s
(b) QAM-C1
(c) QAM-C2

Figure 1: Recognition efficiency of the diagnosis in case of malaria. M: malaria; T: typhoid fever; Y: yellow fever; D: dengue; Other: other disease. The line with circles is the recognition efficiency when the measure is done on the first 6 qubits (symptoms) while the line with empty square is the recognition efficiency when the measure is done on the last 4 qubits (disease)).

| QAM   | $\Lambda$ | $P_r/P_s$ Measure on the 6 first qubits | $P_r/P_s$ Measure on the 4 last qubits |
|-------|-----------|----------------------------------------|----------------------------------------|
| Ezhov’s | 16        | 0.0638                                 | 0.7780                                 |
| C1     | 19        | 0.0638                                 | 0.7780                                 |
| C2     | 13        | 0.0880                                 | 0.9550                                 |

Table 4: Relevant parameters of Ezhov’s, QAM-C1 and QAM-C2 methods in case of the diagnosis of yellow fever.
Figure 2: Recognition efficiency of the diagnosis in case of typhoid fever or dengue. M: malaria; T: typhoid fever; Y: yellow fever; D: dengue; Other: other disease. The line with circles is the recognition efficiency when the measure is done on the first 6 qubits (symptoms) while the line with empty square is the recognition efficiency when the measure is done on the last 4 qubits (disease).

Figure 3: Recognition efficiency of the diagnosis in case of yellow fever. M: malaria; T: typhoid fever; Y: yellow fever; D: dengue; Other: other disease. The line with circles is the recognition efficiency when the measure is done on the first 6 qubits (symptoms) while the line with empty square is the recognition efficiency when the measure is done on the last 4 qubits (disease).
As we build the Quantum Associative Memory it collapses, with a good probability, to a correct state of a particular disease when only a few symptoms or all symptoms of this disease are introduced. But, generally it is the common symptoms which are easily identified with some particular symptoms and it is not easy to find material to identify the other particular symptoms in rural or semi-urban health center. It will be great to have a Quantum Associative Memory which can identify an infection or multi-infection with the lowest rate of particular symptoms and the common symptoms.

One way to get this issue is to invert the amplitudes of probability of the states of symptoms which are not excluded during the learning step, after the identification of the center of query. Remember that the center of the query is one of the state gave in Table 1 which represents the diseases. For this issue, the Algorithm 2 will be rewriting as Algorithm 3.

**Algorithm 3**: Improve Quantum Associative Memory with distributed query for diagnosis #2

1. $|0_10_2\ldots0_n\rangle \equiv |\bar{0}\rangle$: {Initialize the register}
2. $|\Psi\rangle = A |\bar{0}\rangle = \frac{1}{\sqrt{N-M}} \sum_{x \notin M}^{N-1} |x\rangle$: {Learn the patterns using exclusion approach which can be made by the Binary Superposed Quantum Decision Diagram (BSQDD) proposed by Rosenbaum (see [14] for detail)}
3. {Invert the amplitudes of probability of states corresponding to symptoms of the center which are not excluded.}
4. Apply the operator oracle $I_6 \otimes O_4 = O$ to the register;
5. Apply the operator diffusion $D_6 \otimes I_4 = D$ to the register;
6. Apply operator $I_6 \otimes I_M = I_M$ to the register;
7. Apply the operator diffusion $D_6 \otimes I_4 = D$ to the register;
8. repeat
9. Apply the operator oracle $I_6 \otimes O_4 = O$ to the register;
10. Apply the operator diffusion $D_6 \otimes I_4 = D$ to the register;
11. $i = i + 1$;
12. until $i > \Lambda - 2$
13. Observe the system.

With the same data used to build the Table 5 with the QAM-C2 method, we obtain the Table 6.

| Number of common symptoms | $P_c/P_w$ | $\Lambda$ |
|---------------------------|----------|----------|
| 0                         | 1.6900   | 0.2775   | 2       |
| 1                         | 2.0736   | 0.1391   | 11      |
| 2                         | 0.9180   | 0.4712   | 12      |
| 3                         | 1.3156   | 0.7503   | 9       |

Table 6: Recognition efficiency in case of malaria when the common symptoms are introduce and the phase inversion.

The fewest of particular symptoms and the great majority of common symptoms (especially fever, headache and vomiting) give the best probability of retrieving. Let us see it with two particular cases already mentioned with the QAM-C2 method.

1. Only one particular symptom of malaria is introduced and the three common symptoms (Table 7 and Figure 4).
2. Two particular symptoms of malaria, two particular symptoms of typhoid fever and one symptom that is only common to malaria and typhoid are introduced (Table 8 and Figure 5).
Table 7: Relevant parameters of the QAM-C2 method in case of the diagnosis of malaria.

| Method            | $\Lambda$ | $P_c/P_w$ | Measure on the 6 first qubits | Measure on the 4 last qubits |
|-------------------|-----------|-----------|-------------------------------|-------------------------------|
| with phase inversion | 10        | 6.5210    | 15.1820                       |
| without phase inversion | 13        | 0.3921    | 0.3325                        |

Table 8: Relevant parameters of the QAM-C2 method in case of the diagnosis of malaria with typhoid fever.

| Method            | $\Lambda$ | $P_c/P_w$ | Measure on the 6 first qubits | Measure on the 4 last qubits |
|-------------------|-----------|-----------|-------------------------------|-------------------------------|
| with phase inversion | 17        | 0.0650    | 2.0089                        |
| without phase inversion | 2372      | 0.0348    | 1.9408                        |
Overview on the simulation

All the simulation and results were made by writing the algorithms in C++ language. The input register is the first 6 qubits which compute symptoms, while the output register is the last 4 qubits (see the database given in Section A). A prototype of software, called QnnDiagnos (Quantum neural networks for the Diagnosis), was designed in order to provide a user-friendly interface to physicians. It is developed with the open source version of C++ library Qt4 (see Figure 6).

To use the software the physician first chooses the number of symptoms that he will introduce in the QAM (at least one symptom and a maximum of six symptoms), but it is not needful to introduce this number of symptom. This can be done before or after observations or discussion with the patient. Secondly, he introduces these symptoms, according to what he observes and the answers give by the patient, by clicking on the symptoms corresponding buttons on the interface. There are three tabs for symptoms of the four diseases (S1, S2 and S3). Thirdly, he obtains the diagnosis by comparing the recognition efficiency of the QAM for each disease gives in tab "Results". It is noteworthy that simulations are made on "classical computer", so each step of computation can be examined and recognition efficiencies calculated. So the disease with the greatest recognition efficiency can be view as the corresponding disease of the patient.

5 Conclusion

The use of quantum associative memory can be helpful to diagnose tropical diseases. The memory can distinguish single infection to multi-infection and do not need a lot of data to make the diagnosis; it needs few symptoms of disease and the common symptoms as shown on Figure 7. As shown in the recognition efficiency, the phase-inversion introduced in the original algorithm increases the capacity of the memory to make a good diagnosis. The memory can be a good alternative to help physicians without experience or laboratory to diagnose malaria, typhoid fever, yellow fever and dengue which are four tropical diseases sometime confused, using only clinical symptoms (some symptoms are clinical symptoms while others are biological symptoms which need laboratories). For future works, we plan to improve our database and increase the number of tropical diseases that the memory can recognize.
Figure 6: The interface of the software has a tab which gives information on what happens or on what should be done; a tab which gives the results of the diagnosis; and finally a set of buttons to introduce data and run the simulation to have the diagnosis.

Figure 7: Evolution of recognition efficiency when one particular symptoms is inserted with common symptoms for each disease.
A Symptoms of each group of diseases

A.1 Malaria
1. Cold sensation;
2. Paleness;
3. Severe anemia ($Hb < 5 \text{g/dl}$ or $Ht < 15\%$);
4. Profuse sweat;
5. Stiffness;
6. Splenomegaly;
7. Dark urine and oliguria (urine output $< 400 \text{ml}$);
8. Nausea;
9. Pulmonary edema;
10. Spontaneous hemorrhage;
11. Macroscopic hemoglobinuria;
12. Hyperparasitemia (parasitic density $> 5\%$);
13. Repeated generalize convulsions.

A.2 Typhoid fever
14. Relative bradycardia;
15. Epistaxis;
16. Saburral tongue;
17. Anorexia;
18. Typhoid state;
19. Rumble in the right iliac cavity;
20. Yellowy diarrhea;
21. Constipation;
22. Delicate splenomegaly;
23. Abdominal pinkish marks.

A.3 Yellow fever
24. Iterus (jaundice);
25. Renal troubles;
26. Vomiting of darkness blood.

A.4 Dengue
27. Retro-orbital pain;
28. Leukopenia;
29. Hemorrhagic manifestations;
30. Positive Rumple-Leede phenomenon;
31. Severe hemorrhages;
32. Serous effusion;
33. Maculopapular eruption;
34. Articular pains;
35. Thrombopenia ($\text{platelets} < 100000 / \text{mm}^3$);
36. Elevation of the hematocrit $\geq 20\%$ of is normal value.

A.5 Common to the malaria and the typhoid fever
37. Tire;
38. Abdominal pains;
39. Hepatomegaly.

A.6 Common to the malaria and the dengue
40. Shock.

A.7 Common to the malaria and the yellow fever
41. Chills; 42. Dehydration.

A.8 Common to the yellow fever and the dengue
43. Muscular pains.

A.9 Common to the malaria, the yellow fever and the dengue
44. Trouble of the consciousness.

A.10 Others (common to the four diseases)
45. Fever (> 38°C); 46. Headaches; 47. Vomiting.

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