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A Novel Medical Data Acquisition and Transmission Technique

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Abstract: ***In this article, we propose a new technique of acquisition by sensors, towards a cellular telephone equipped with a mobile application, of multidimensional physiological signals, by Bluetooth technology and especially by manual input, for predictive tests and their transmission on a Mobile Cloud Computing. The experimental plan consists of combining two multi-sensors and a test marker to simultaneously acquire the physiological signals and values of people on a tablet or smartphone. Our contribution consists not only in deducing, from these signals, formulae for the determination of other values, in particular the hematocrit level of the Blood Formula Count (BFN), the body mass index (BMI), the creatinine clearance (CrCl), but also in developing a mobile application capable of displaying these acquisition results and, by detection algorithms, of predicting pathologies. We also offer our Mobile Cloud Computing architecture and simulate Big data analysis with Matlab.***

Keywords: Physiological signals, sensors, Mobile Cloud Computing, Detection algorithms, Big Data analyses

1. Introduction

Talking about the acquisition of multidimensional physiological signals, their processing and transmission by mobile phone is something very important. This therefore requires an explanation. Physiological signals are physical quantities taken from the human body by means of special sensors. These sensors are either:

- Invasive in which case collection is intravenous or access to plasma fluid
- Non-invasive; in this second case, the sample is taken without intravenous penetration or extraction of plasma liquid.

They are multidimensional when several different signals are involved. It is they who are transmitted via the mobile telephone network.

In such a context, the acquisition via two multi-sensors of multidimensional physiological signals becomes important for the patient and his treating physicians, because it allows remote monitoring or observation of the patient's condition alerts, remote expertise and remote assistance or remote specialists to the treating agents close to the patient.

Faced with this dilemma, several studies have tried to find an effective solution by proposing the multi-sensor platform for monitoring geographical positioning and behavioral signals[1], sensor networks for medical monitoring application[2], telemetric measurement of biological signals selected by Bluetooth technology[3], wireless medical surveillance system at lower cost, and transmission to a medical alarm station [4].

In order to make our contribution, we propose the acquisition by Bluetooth of 10 physiological signals which are : systolic blood pressure (SBP), diastolic blood pressure (DBP), blood pressure (BP), heart rate or pulse rate (HR), pulsed oxygen saturation (SpO2), blood glucose or blood sugar level (Gl), Creatinine characteristic of renal function (Cr), LDL cholesterol or (LDL-Cholesterol), uric acid in the blood (Ur), hemoglobin (Hb), patient temperature (T°). From these values acquired by our device, we can extract the following formulas: creatinine clearance (CrCl), hematocrit (Ht), total renal blood flow (TRBF), body mass index (BMI).

The weight (Wt), height (Ht), sex (S), age (Ag) and blood group are also entered manually. We create a library of symptoms, which are collected on the client and entered manually in our application: headaches, cough, vomiting, blurred vision, diarrhea, constipation, fatigue, nose bleeds, abdominal pain, and general appearance of the skin.

At this stage, our first level algorithms test pathologies directly related to these physical values in order to deduce their normal, abnormal or critical character. Pathology tests and predictive diagnostics are thus transmitted to our Mobile Cloud Computing, via the telephone network chip embedded in our mobile terminals, which in turn transmits them to the attending physician, specialists or simply to the patient's relatives.

The rest of this article is organized as follows: Section 2 develops the state of the art in the research field. Section 3 poses the problem. Section 4 outlines our contribution. Section 5 discusses the limitations of our contribution's work by presenting the actual use for patient reception in our emergency departments and the benefit for telemedicine of our multi-sensor process for the simultaneous acquisition of multidimensional physiological signals. Section 6 concludes and opens the way for our work.

2. Related Works

2.1. The multi-sensor platform for monitoring geographic positioning and behavioral signals [1]

In this study, the author proposes a multi-sensor architecture for remote measurement and physiological data transmission that is as energy-efficient as possible. It consists of 6 parts:

- The design and implementation of a modular architecture,

with a certain number of sensors and modules, capable of transmitting physiological data remotely on a server.
- A contextual presentation of the field of his research
- The state of the art on designed multi-sensor systems
- The realization of the multi-sensor platform
- Strategies and algorithms to save battery power
- Test results and discussion.

The Limits:
This research dealing with a true multi-sensor process of physiological signals elucidates well the technologies to implement to transmit remotely via tablet PC, PDA and Smartphone data to a remote server. However, the study is predictive only for targeted diseases in a European population: obesity, diabetes and cardiovascular diseases.

2.2. Sensor networks for medical monitoring application [2]

The author of this study aims to set up a sensor network system capable of monitoring the physiological characteristics of elderly people and transmitting these data to a care or logistics center. This work consists of three parts:
- Comparison of Unicast and Multicast distribution schemes for physiological data transmission
- The heterogeneity of the nodes with patients equipped with geographically close sensors
- The aggregation of physiological data in this context of heterogeneous nodes.

Limits:
As in previous studies, this study aims to implement better processes for acquiring physiological signals on patients, but focuses much more on optimal transmission technologies, based on geographically identified patient samples.

2.3. Telemetric measurement of selected biological signals using Bluetooth technology [3]

The author proposes an architecture for transmitting medical data from a mobile equipped with Bluetooth technology, in the same way as [1]. This study, however, presents a limited number of physiological signals transmitted to a remote server.

2.4. Wireless medical surveillance system at lower cost, and transmission to a medical alarm station [4].

The author proposes an architecture for medical surveillance of people at home, using sensory sensors around people. Again, the number of physiological signals is limited.

2.5 Mobile-health: a review of current state in 2015[5].

This literature review on the state of the art in m-health application or mobile e-health application, shows the latest emerging technologies,

Limits:
In view of all these technologies, we note that they are efficient, but very few of them offer the acquisition of several signals on a tablet for transmission via the mobile network to a specialized central and then to specialists.

2.6 Using Smart Phones and Body Sensors to Deliver Pervasive Mobile Personal Healthcare [6]

The author of this article proposes a physiological data transmission architecture, notably ECG, via a mobile phone to a remote server. Above all, it shows that storing this data on the mobile phone before it is transmitted saves more energy than continuously transmitting it to the remote server.

3. The Problem

The above review of existing work reveals that the authors have done excellent work in the field that identifies physiological signals. However, very few of them have directed their work towards designing an innovative tool for acquiring several physiological signals via Bluetooth, for display on a mobile terminal, for predictive tests in the form of a health check, and their transfer to a cloud computing, via the mobile telephone network.

That said, none of this work could expose an acquisition of so many different physiological signals, by Bluetooth technology and direct input, through three multi-sensors, capable of automatically acquiring 10 physiological signals and deducing 4 other physiological parameters. At least, the work that has addressed the acquisition by Bluetooth of multidimensional physiological signals is limited to a maximum of three physical values, and therefore insufficient for a health check-up; even Arthur Zang's CARDIOPAD in Cameroon deals specifically only with heart disease [7].

The traditional check-up requires many different examinations with expensive equipment that is difficult to move easily. Thus, we have tried to propose our multi-sensor platform for the acquisition and transmission of the 10 physiological signals and other deduced values. This, in order to reduce the time of the results to practically 10 minutes maxi, with an accessible and mobile material.

Thereafter we propose their modeling in our mobile application. At this stage, our first level algorithms test pathologies directly related to these physical values in order to deduce their normal, abnormal or critical character. Then, our advanced algorithm makes act the symptoms of the person in order to refine a predictive diagnosis of pathologies, before their transmission via the mobile telephone network towards our cloud computing.

4. Material and Method

4.1. Implementation of our Mobile Medical Data Transmission

Our system of acquisition, processing and transmission of physiological data by Mobile Cloud Computing, for an omnipresent medicine, holds in four points:

Our Mobile Cloud Computing (MCC) architecture (Fig.1)

The implementation of our pathology prediction algorithms.
Our mobile and web application.
Simulation of our Big Data analysis.

4.2. Multi-sensor platform and our Mobile Cloud Computing (MCC)

We present here the modules of our multi-sensor platform for the implementation of our MCC shown in Figure 1. We used a miniaturized and economical multi-sensor using a low power consumption battery. This "5 in 1 health monitor" allows simultaneous acquisition: systolic blood pressure (SBP) in millimeters per mercury (mmHg), diastolic blood pressure (DBP) in millimeters per mercury (mmHg), blood pressure (BP), heart rate or pulse (HR) which is the number of heart beats per minute (Bpm), "pulsed" oxygen saturation (SpO2) quantify in %, body temperature in degrees Celsius (T°), and also ECG signal.

Figure 1: synoptic diagram of our Mobile Cloud Computing

Our second economical multi-sensor "4 in 1 Hemoglobin monitor" acquires us: blood sugar or blood sugar level (Gl)in g/l, bad LDL cholesterol or (LDL-cholesterol), uric acid in the blood (UrAc), hemoglobin (Hb). From the hemoglobin value, we derive another parameter from the Blood Formula Count (CBC) which is hematocrit (Ht). Then we manually enter the following values: The creatinine characteristic of renal function (Cr) that we obtained with our urine test marker. The other body values manually recorded and filled in are: weight (Wt), height (Hg), sex (S), age (Ag). We then derived the following formulas: creatinine clearance (CrCl), total renal blood flow (TRBF), body mass index (BMI).
Through observation and questioning of the patients, we obtained, in addition to the blood group, the following symptoms which were recorded manually, mainly nausea, headache, cough, vomiting, diarrhea, constipation, fatigue, nose bleeds, abdominal pain, blurred vision, general skin appearance, to name a few.

Figure 2: Measurement with the "5 in 1 Health

Monitor" respectively: Blood pressure, SpO2, Heart Rate, ECG, IR temperature.

Figure 3: Other measurement equipment of Ihealth to collect data: SBP, DBP, BP, HR and Gl of 10 people

4.3 Creatinine meter with our urine test marker

The urine specimen is collected in a clean box and sold in pharmacies. We test the urine immediately after collection. Semi-quantitative results are obtained by visually comparing the blocks of coloured reagents on the marker with the colors indicated on the housing of the markers.

Figure 5: Urine test marker for creatinineemia

4.4 Normal physiological signal values [8], [9]

Any value outside the normal range is abnormal. The critical values and their margins are defined according to a threshold of ±10 or ±20 that we have established according to the basic standards of the World Health Organization (WHO) [8]:

$$BP = \frac{SBP}{DBP} \quad (1)$$

Hypertension is expected to be above 14/9 (140/90 mmHg). Any value of SBP>140 and DBP>90 is abnormal. We consider any SBP or DBP value already above this threshold of ±10mmHg as critical (Ex: 140 <SBP<150 is abnormal while 150<SBP is critical).

The Heart Rate (HR, or Heartbeats per Minute, has normal values (60-100 Bpm). We consider it critical if it is at least above or below the normal values of ±20 Bpm: (40<HR<60 or 100<HR<120 is abnormal while HR<40 or HR>120 is critical). The critical range is set to ±20 Bpm.

For oximetry, "pulsed" oxygen saturation (SpO2) is normal between 96% and 100%. For 76%<SpO2<96% or 100%<SpO2<120%, it is considered abnormal, while SpO2<76% or SpO2>120% is critical. The critical margin being ±20%.

For Glycemia, the normal blood sugar (Gl) level is between 0.6 and 1.10 g/l. (0.5<Gl<0.6 or 1.10<Gl<1.20 is abnormal while Gl<0.5 or Gl>1.20 is critical). The critical range is set to ± 0.10 g/l.
For kidney Values, creatinine (Cr) is normal between 60 and 120 µmol/l. (40<Cr<60 or 120<Cr<140 is abnormal while Cr<40 or Cr>140 is critical). The critical range is ±20 µmol/l.

Creatinine clearance (CrCl) for men [10][11]:

$$CrCl = \frac{(1{,}23 \times (140 - age) \times weight(kg))}{(creatinnemia\ in\ \mu mol/l)} \quad (2)$$

For women [10]:

$$CrCl = \frac{(1{,}04 \times (140 - age) \times weight(kg))}{(creatinnemia\ in\ \mu mol/l)} \quad (3)$$

If clearance is less than 80 ml/min, we have a kidney failure (KF) alert. 60<Cr<80 is therefore abnormal while ClCr<60 is critical). The critical range is ±20 µmol/l. Any creatinine level above 120µmol/l in adult males (100 µmol/l in females) and 100 µmol/l in the elderly is an alert value.

The total renal blood flow is given by:

$$TRBF = \frac{600}{(1 - hematocrit)} \quad (4)$$

This blood flow gives practitioners a clue. 1200 ml/min is the normal value. Any lower value is abnormal and (-200 ml/min) of this threshold is critical.

Uric acid (Ur) is dosed by a blood test. Its normal value is between 150 and 300 mmol/l for women and (300-400 mmol/l) for men. The critical range is±20 mmol/l.

The level of bad LDL cholesterol or (LDL-Cholesterol) must be less than 1.6 g/l; if higher then abnormal, the critical margin being set at ±0.20 g/l.

Blood Function Number (BNF) variables: hemoglobin (Hb) is between 12 and 14.5 g/100ml in men and 11 and 13 g/100ml in women. The critical range being ±2 g/100ml is critical. The hematocrit level (Ht in %) is 3 times Hb.

$$Ht = 3 \times Hb \quad (5)$$

In terms of body data: weight (Wt) makes it possible to consider the BMI, body mass index, knowing the patient's height. The body mass index is:

$$BMI = \frac{(weight\ in\ kg)}{(height^2\ in\ m)} \quad (6)$$

It is used to monitor a diabetes and overweight alert. If BMI<18.5 then it is thinness. BMI between [18.5, 24.9], it is normal, between [25, 29.9], we are overweight, and if BMI > 30, we are obese.

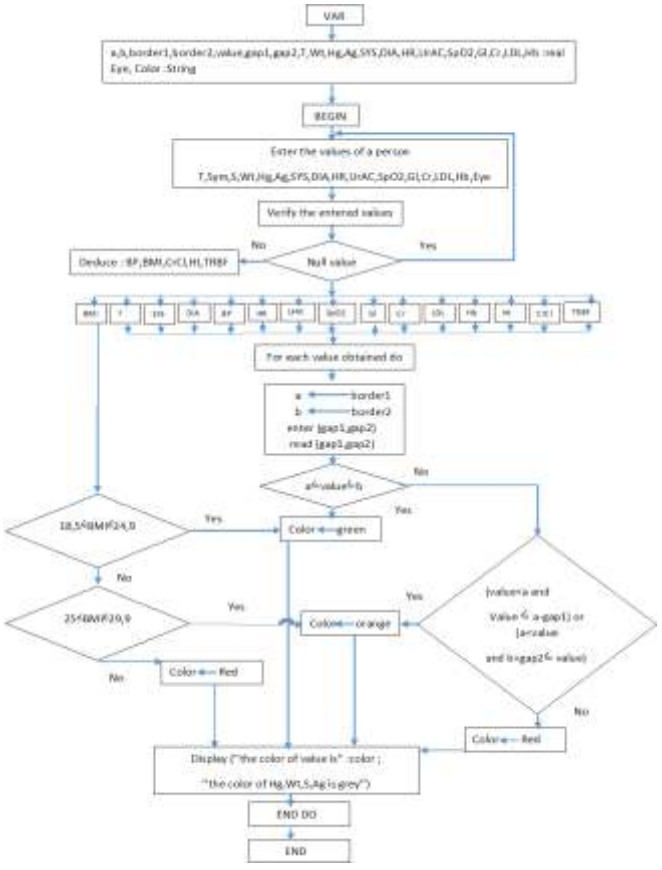
The temperature (T° in °C), has for normal value between (32-37°). The critical margin being ±2° C.

The Size (T) is in meters. The sex (S) takes the value M or F. Age (Ag) is in years. White (Ye) eye color indicates normal, yellow or red means critical.

4.5 Implementation of our two detection algorithms

4.5.1 Algorithm for evaluating signal values

In this algorithm, we take the value of an acquired signal x, this value is compared with the normal values. Based on this comparison, we can say whether it's normal, abnormal or critical, by playing the green, orange and red color games of our first algorithm



4.5.2 Algorithm #2 to refine disease prediction

Algorithm completed and final for pathology prediction based on symptoms on the person examined:

This algorithm is based on the modified Bayes law to determine the patient's percentage probability of making a disease. It confirms or disproves the alerts obtained from the first algorithm on the patient's medical values.

This is the general formula of Bayes Law:

$$p(A/B)=\frac{p(A)\cdot p(B/A)}{p(A)\cdot p(B/A)+p(A^{\cdot})\cdot p(B/A^{\cdot})} \quad (7)$$

For us, we take any pathology, we present its known general symptoms. On the person examined, we collect with our application the number of apparent symptoms. We divide this number by the total known number of symptoms, which gives us a percentage for that person to do that disease.

Let Sj : symptom j and Pi : pathology i; For example:

P1={S1 ,S2,S4}
P2={S2 ,S3,S4}
P3={S7,S8}
P4={S2 ,S3,S5,S6,S9}
P5={S10}

This gives us the following matrix:

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
P1	1	1	0	1	0	0	0	0	0	0
P2	0	1	1	1	0	0	0	0	0	0
P3	0	0	0	0	0	0	1	1	0	0
P4	0	1	1	0	1	1	0	0	1	0
P5	0	0	0	0	0	0	0	0	0	1

Now let write our second predictive algorithm

Algorithm

```
BEGIN
For i from 1 to 10
Var temp[i] =0//variable to keep the number of symptoms in a pathology
 For j from 1 to 10
 If ( P[i].S[j]=1)
temp[i]= temp[i]+1
endif
end for
Percentage = temp[i]/ P[i]
end for
END
```

REMARQUE:
To find the percentage we took temp[i] and divided it by the total number of pathology P[i]:

5. Results and discussions

5.1 Data measurement with our MCC

The color set indicator for signals and values is defined by our protocol as follows:

Normal 🟢 abnormal 🟠 Critical 🔴 Nothing ○

Table 1: Values acquired by our MCC on a given patient

Value	T (°C)	Wt (Kg)	S (M or W)	Hg (g/l)	Age (year)	SYS (mmHg)	DIA (mmHg)	HR (Bpm)	HP (S/D)	UrAc (mmol/l)
09/24/2018	33	85	M	1,80	45	120	77	80	12/7,7	160
Conclusion	🟢	○	○	○	○	🟢	🟢	🟢	🟢	🟢
10/05/2018	38	83	M	1,80	45	133	88	79	13,3/8,8	165
Conclusion	🟢	○	○	○	○	🟢	🟢	🟢	🟢	🟢
Indicator	▼	▲	○	○	○	▲	▲	▼	▲	▲

Continued from **Table 1**

Value	SpO2 (%)	Gl (g/l)	Cr (µmol/l)	LDL (g/l)	Hb (g/100ml)	Ht (%)	BMI (%)	Eye (W or Y)	CrCl (ml/min)	TRBF (ml/min)
09/26/2018	97	1,8	80	1,8	12	36	26,23	White	128,07	937
Conclusion	🟢	🔴	🟢	🔴	🟢	🟢	🟠	🟢	🟢	🟠
10/05/2018	96,7	1,83	82	1,86	12,5	37,5	25,61	Yellow	118,27	952,38
Conclusion	🟢	🔴	🟢	🔴	🟢	🟢	🟠	🟠	🟢	🟠
Indicator	▼	▲	▲	▲	▲	▲	▼	▲	▼	▲

Table 2: Patient data obtained by Ihealth equipments

Value	T (°C)	Wt (Kg)	S (M or W)	Hg (g/l)	Age (year)	SYS (mmHg)	DIA (mmHg)	HR (Bpm)	HP (S/D)	Gl (g/l)
09/24/2018	33	85	M	1,80	45	120	77	80	12/7,7	160
Conclusion	🟢	○	○	○	○	🔴	🔴	🟢	🔴	🔴
10/05/2018	38	83	M	1,80	45	133	88	79	13,3/8,8	165
Conclusion	🟢	○	○	○	○	🔴	🔴	🟢	🔴	🔴
Indicator	▲	▲	○	○	○	▲	▲	▼	▲	▲

Table 1 clearly indicates, based on our first algorithm, that the patient monitored by our device is at risk of diabetes, cardiovascular disease due to high cholesterol, overweight, malaria or infection due to eye color. ***Table 2*** shows us that the other patient followed by the glucometer and the wireless blood pressure monitor of *Ihealth* society, based on our algorithm presents risks of high blood pressure (value >14/9), and diabetes.

In both cases our first algorithm was 100% effective in showing the risks of pathology.

The symptoms observed on our first patient are: blurred vision in the left eye, fatigue, weight loss, nausea, headaches. From the symptom dictionary, we obtained the following results:

Patients 1: first risk, Diabetes 3/10=30%, second risk, Cardiovascular disease CVD 1/5= 20%. These results are confirmed by our doctor who confirmed the correlation that exists between cardiovascular disorders, diabetes, and overweight. As for abnormal blood flow, there is no information from creatinemia and its clearance.

Patient 2 follow-up on *Ihealth* equipment: first risk 2/6=33% ; second risk 3/10= 30%. These results are also confirmed by our doctor who confirmed the correlation between high blood pressure and diabetes.

In both cases our second algorithm was 100% effective in classifying pathologies in order of probability. From these two cases, we extended the work to 10 other patients, on cardiovascular disease (CVD) or MVC in French, high blood

pressure (HBP), diabetes (D), Kidney Failure (KF), and malaria (Mal). Here are some results we obtain in ***Table 3***.

Table 3: measure on 10 persons

Desease \ Patient	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
CVD (Cardiovascular deseases)	83	20	66	0	0	66	83	0	0	75
BP (High blood pressure)	50	0	0	82	20	42	57	75	0	50
Diabete	0	40	42	57	0	0	0	0	75	50
KF (Kidney failure)	0	50	0	85	0	40	0	0	20	0
Mal (Malaria)	0	0	0	0	85	0	33	33	33	0

Figure 7: Screen display of our mobile application named URGENCYPAD

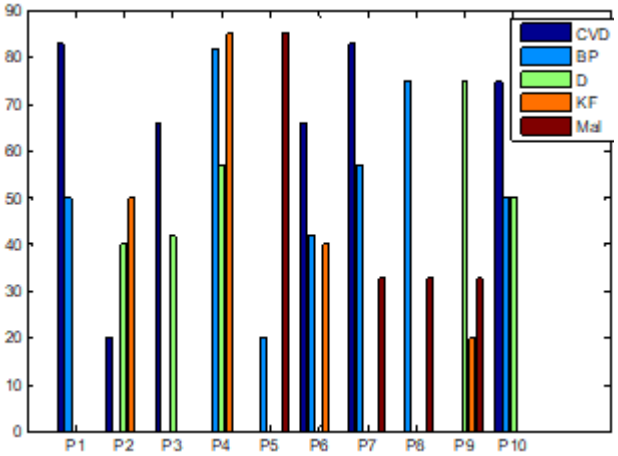
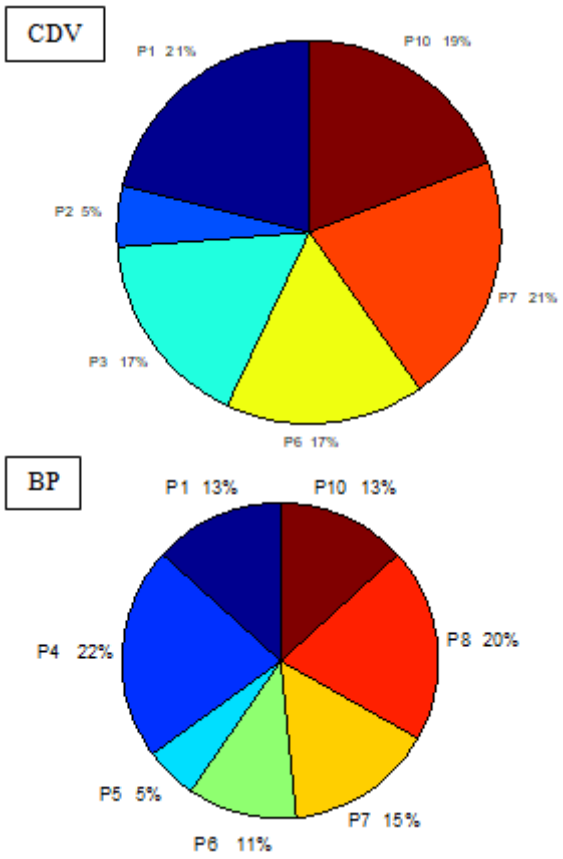


Figure 8: Big data analysis simulation In Matlab.



Continued from Figure 8: Big data analysis simulation In Matlab.

The commentary of this simulation clearly indicates that, according to the first sector graph, in our study population patients P1, P10, P7, and P6 have a higher risk of cardiovascular disease. According to the second sector graph, patients with P1, P7, P6, P8 and P10 have a higher risk of high blood pressure. When we take into account the opinion of medical specialists who confirm the correlation between high blood pressure and cardiovascular diseases, patients P1, P7 and P10 who present these two risks are formally identified as people who may develop cardiovascular diseases.

6. Conclusion

Our work has enabled us to design and implement a new Mobile Cloud Computing (MCC) architecture, which has made it possible to improve multi-physiological data acquisition processes, in the form of a health check, and to transmit them by mobile via an application installed on a tablet. This application is underpinned by an algorithm for evaluating these data in relation to their normal values and predicting pathologies. We were able to simulate Big Data analysis in Matlab. Our new medical data acquisition and transmission technique has proved to be innovative compared to what we have read in the literature. Our next study aims to establishing a new security scheme for the transmission of medical data, using an algorithm combining Young's tables and the RSA algorithm.

7. Outlook

Our next study aims to establishing a new security scheme for the transmission of medical data, using an algorithm combining Young's tables and the RSA algorithm.

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