Manage well-being through a breathing control app

Francesco Bruno, Nicolò Picchi, Gaetano Sferrazza, Lorenzo Tonelli
f.bruno10@studenti.unipi.it, n.picchi3@studenti.unipi.it, g.sferrazza@studenti.unipi.it, l.tonelli4@studenti.unipi.it

ABSTRACT

JustBreathe is an application developed for Android devices that monitors the user's breathing and measures its quality by giving a score from 0 to 100. The score provided by the application indicates how well the user's breathing conforms to a given breathing time pattern . In the scientific literature different breathing patterns have been identified, each of which is best suited to address specific psychological problems, such as stress, anxiety and panic states. To record a breathing session, the user must lie down, place the phone on the abdomen then press the appropriate button of the application to begin. The experiments conducted show that the application is easy to use and that the smartphone can become an excellent tool to monitor and guide the user's breathing, helping him in managing his well-being.

1 Introduction

Breathing is one of the first activities that every human being learns unconsciously even before being born. Many researches state that, although it is a trivial activity, it is fundamental to manage emotions or states of confusion. Several breathing patterns have been identified that can positively influence the psyche of the person and lead him to be more efficient in the work he does. The most common breathing pattern is 4-7-8, which respectively indicate the time, in seconds, of inhalation, apnea and exhalation. If followed cyclically it can induce the user to positive psycho-physical states, increasing the feeling of control and reducing the perception of stress. The correct intensity and respect for the rhythm of inspiration and exhalation are important activities to quickly obtain positive mental states. The medical equipment needed to monitor breathing is varied and often not accessible to everyone. A practical and economical solution is the use of your smartphone. Mobile technology has made great strides, especially with regard to the sensors integrated into smartphones, which are increasingly precise and energetically more efficient. To monitor the quality of the user's breathing, it was decided to use the accelerometer of the own smartphone by installing the specially developed application, JustBreathe. This performs signal processing on the signal obtained from the accelerometer and applies a scoreBreathing function to measure the goodness of the user's breathing according to a chosen pattern.

2 Similar Applications & Related works

In the Android PlayStore, there are already other applications that should guide the user in breathing but none of them use the accelerometer to monitor the quality of breathing. Most merely provide audio signals to synchronize the user's breathing for a specific pattern.

Applications such as BreathApp [1], Breathe [2], are part of the category of Respiratory Advisor Applications, which guide the user to breathe through sounds emitted with a constant frequency from the phone. The user simply personalizes the breathing session by choosing background sounds, session duration, and breathing patterns. Breathe [3] is another app that, in addition to signaling the breathing rhythm that the user must follow, illustrates a function on the screen similar to a sinusoidal signal. For now, no Android applications have been found that generally return feedback to the user indicating the quality of the breathing session.

In the academic field it has been possible to observe situations in which the accelerometer has been used to measure the breathing quality of patients for remote breathing control systems [4] using machine learning techniques on very large datasets. While another study claims to calculate the breathing rate through the use of accelerometer integrated into an arduino [5]

3 Architecture

The application is mainly based on treating the signal obtained from the accelerometer, filtering it and, through a function created ad-hoc, calculating the breathing goodness of the session by showing it on the graphical interface. From the signal point of view we can identify two functional blocks: 1) Signal Processing and 2) Breathing Signal Scoring that will be explained in the subsections of the chapter.

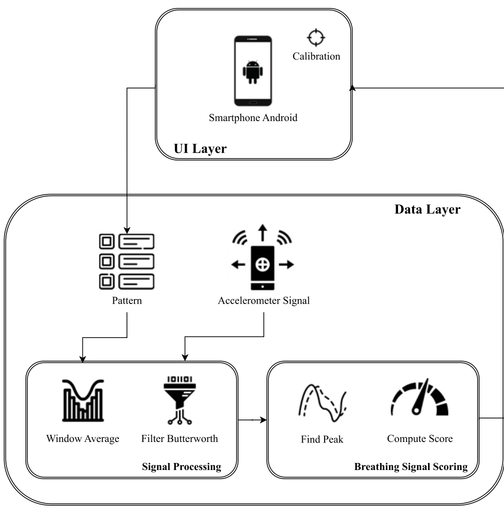


Figure 1: Functional architecture has been reported.

3.1 Signal processing

In this phase, the breathing signal obtained from the smartphone accelerometer was treated. In figure1, we can see an example of breathing obtained from a Samsung smartphone A33. We have decided to work only with the z component of acceleration. To cancel the component of gravity that affects the acceleration value, a calibration phase was carried out that brings the raw signals to the height of ordinate 0. Android provides constants, such as Linear_gravity to cancel the influence of weight force on the data recorded by the accelerometer. However, looking at the values on paper, this method of cancellation led to reaching 0 with low accuracy. So we adopted a calibration that consists of placing the phone on a plane and calculating the average weight force of 100 samples along the z-axis in order to reach 0 with greater precision.

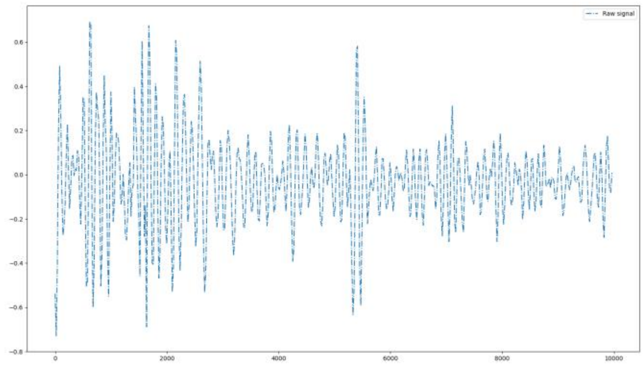


Figure 2: raw signal with respect to the accelerometer's z-axis. The time is measured in milliseconds while the acceleration in meters per second squared.

A windowAverage with a window size of 125 samples is applied to the recorded signal. The signal obtained was not considered valid for making considerations on the quality of breathing, therefore a Butteworth type filter was applied in low-pass mode. The cut-off frequency chosen is 0.25Hz in according to breathing human rate that ranges from 0.2 to 0.4 Hz. An example of a result that we can obtain by applying the window average and then the butterworth filtering is shown in the following figure.

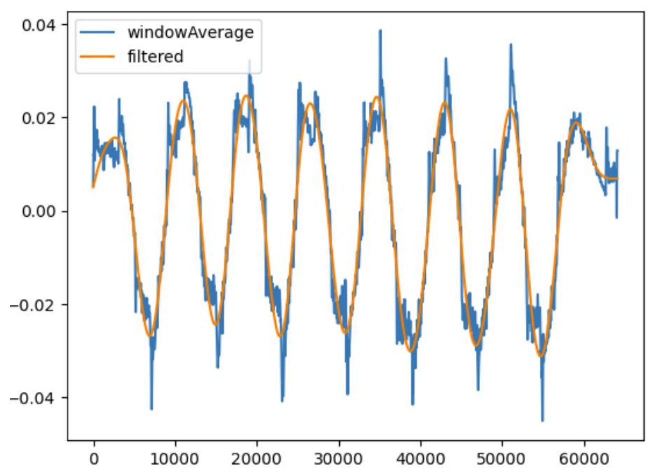


Figure 3: In this plot two graph has been reported: signal obtained with WindowAverage, and it filtered with ButterWorth. Time is measured in milliseconds while the acceleration in meters per second squared.

The filtered signal is the signal that will be measured through the scoreBreathing function. This procedure illustrated through images is applied for each breathing session recorded by the smartphone.

3. 2 Breathing signal Scoring

To measure the goodness of the user's breathing session, a heuristic algorithm has been designed which, taking as input the processed breathing signal and the time pattern chosen by the user, returns to a score between 0 and 100. The higher the score, the higher the quality of breathing carried out by the user. Since the signals coming out of the signal processing phase are pseudo-sinusoidal we thought we would work by observing the peaks of this signal: peaks of local minimum and peaks of local maximum. The jsdp library in Java was used to work with signal peaks [6]. In addition, time differences between one peak and the next were observed.

The function designed to measure the goodness of a breathing is called scoreBreathing() which is based on the quality of the maximum peaks, quality of the minimum peaks and quality of the breathing intervals, quality of breath holding, indicated respectively with q_{max} , q_{min}, q_{int}, q_{hold} . The function returns the score according to the combination of these four indices:

$$S = \alpha_1 q_{max} + \alpha_2 q_{min} + \alpha_3 q_{int} + \alpha_4 q_{hold} \qquad (1)$$

$$\forall \alpha_i \in [0,1] \quad \text{and} \quad \sum_{i=1}^{N} \alpha_i = 1$$

q_{max} is the index that measures how close the local maximum peaks are to their average; this is calculated with a simple ratio of the number of maximum peaks that are close to the mean, within a predefined threshold, with the total number of maximum peaks of the signal.

q_{min} is the index that measures how close the local minimum peaks are to their average; similar to the q_{max} only the q_{min} are calculated.

q_{int} is the index that measures how much the period of inhalation and exhalation corresponds to the chosen pattern; It is obtained by calculating the ratio between the number of exhalatory periods or breaths that are close to the ideal period, within a certain tolerance, with the total number of breaths taken in the session.

q_{hold} is the index that measures the general goodness of the apnea periods of the entire session; It is obtained by calculating the ratio between apnea intervals that are close to the ideal period within a certain tolerance, and the total number of apnea intervals.

For the breathing pattern 404, in which the apnea phase is not present, the Score function (1) does not have the component $\alpha_4\, q_{hold}$.

In the figure, the signal obtained in the previous paragraph is shown, highlighting what are the characteristics that the scoreBreathing analyzes to provide the score.

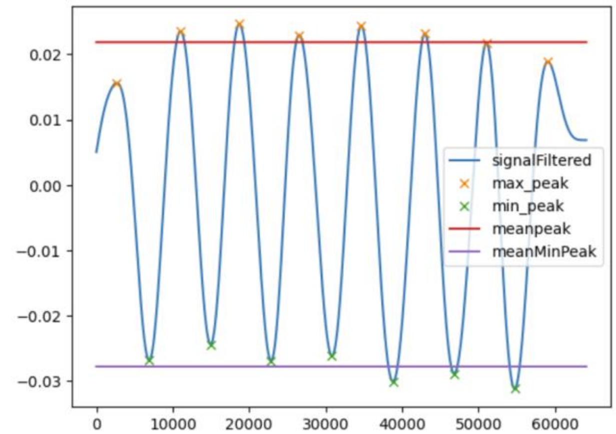


Figure 4: Max and min peaks have been individuated by a cross end relative means have been plot. The time on x-axis is measured in milliseconds while the acceleration on y-axis in meters per second squared.

Tolerance parameters, along with weights, $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ are important because they define the judgment of scoreBreathing.

For example, if the scoreBreathing() takes as input the signal in the figure, with peak_max_tollerance = peak_min_tollerance = 0.001, breath_period_tollerance = 500ms, α_1= α_2= 0.25 ed , α_3 = 0.50, it is obtained as a result of score 90.4. The maximum was not achieved because two peaks of local highs are too far from their average.

It is possible to consult the code of the ScoreBreathing() written in the class FilterManager.pkt of the application.

4 Experimental results

The experiments conducted were necessary to test the reliability of the scoreBreathing function in judging a user's breathing. The goal, therefore, was to prove that with correct breathing sessions, according to the chosen pattern, the score function returned a high score, while for incorrect breathing sessions that returned a low score.

Before launching the reliability test, it was necessary to identify reasonable threshold parameters and how to weigh the indices q_max, q_min and q_int. Once found it was necessary to create the testset. Four users with their Android smartphone installed the JustBreathe application which was used to collect a total of 60 breathing sessions of at least 45 seconds. Half of the sessions were done trying to breathe as best as possible, following the 404 pattern, chosen to conduct the trial. While the other half of sessions were recorded not taking into account the pattern to be followed.

4.1 GUI

Launching the application we can observe in the first screen three rounded panes. Each briefly indicates the breathing pattern and the beneficial result it should induce. Before proceeding, it is strongly recommended to calibrate the accelerometer. To calibrate the phone you must then click on the icon at the top in the shape of a viewfinder and place the phone on a plane. In this way, the influence of the perceived weight force for that specific smartphone is sampled. Once the calibration has been carried out and clicking on a box, a new screen opens that is used to launch the breathing recording session. Recording begins after clicking the play icon located in the center of the screen. Until it is clicked back to the application will record all the time.

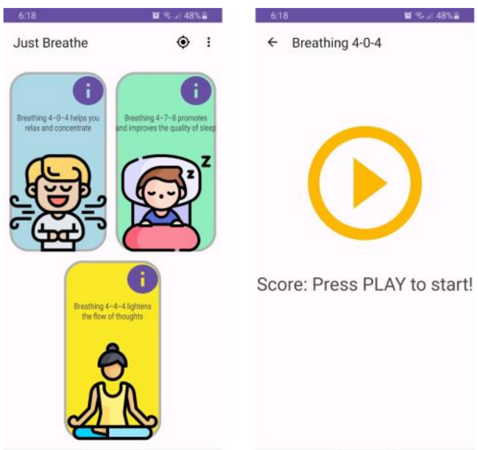


Figure 5a, 5b: From the left we have the first screen of the application. Next we have a breathing session recording screen.

Before launching the recording session it is necessary to lie down on a bed and place the smartphone above the abdomen, with the cover flying towards the navel.

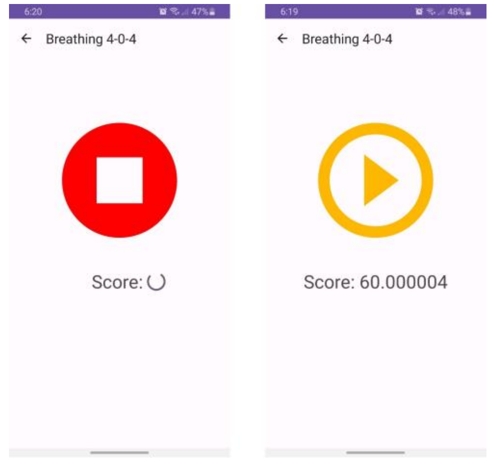


Figure 6a, 6b: From the left we have what the application shows during a recording session. Then we have the score screen.

To know the goodness of the breathing session in progress, simply click the red stop button in the center of the screen. Once clicked, the score for the session will be shown with a score ranging from 0 to 100. See Figure 6b.

For more information it is possible to consult the user manual in the repository.

4. 2 Finetuning hyperparameter

The first recorded sessions were the basis for exploring the nature of the breathing signal and observing the differences between breathing signals from different users. The following considerations were the basis for the choice of hyperparameters:

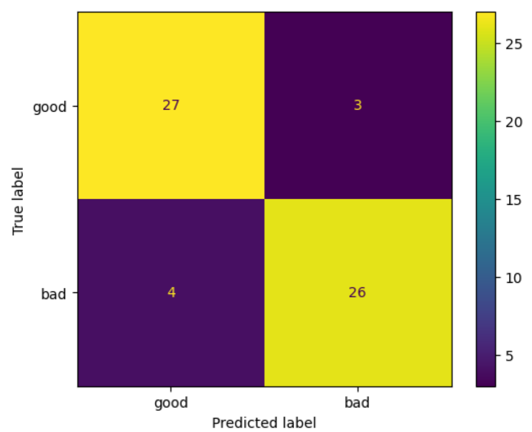
- Each user reported difficulties in respecting the chosen breathing pattern for over 40 seconds. So over 40 seconds the probability of committing inaccuracies was higher.

- Each user has a different abdominal extensibility and sensitivity and therefore a separation of maximum peaks and peaks of minimum more or less wide.

- Two users stated that keeping the breathing rhythm accurate to the ideal one was difficult.

4. 3 Measure of score function reliability

Once the hyperparameters are foundr it has been necessary to collect sessions and set up a supervised testset. For simplicity, the experiments were carried out only for the 404 time pattern. Each session was labeled "good" or "bad", indicating respectively that the user committed to respecting the chosen pattern or not. you can get the testset in the repository on GitHub. The score provided was coded as "good" if between 65 and 100, while "bad" otherwise.



Looking at the results obtained we can say that the score provided by the application is reliable, as the precision, recall and f1-score measurements are almost 90%.

	Precision	Recall	F1-score	Support
"Good"	0.90	0.87	0.88	30
"Bad"	0.87	0.90	0.89	30
Accuracy			0.88	60

Table 1: Metric results have been reported in table.

5 Conclusion

In this study, the JustBreath application was presented, designed to monitor the user's breathing through the use of the accelerometer integrated into the smartphone. To treat the signal obtained from the accelerometer it was necessary to implement signal processing techniques such as the window average and the butteworth filter. The processed signal was finally measured by a scoreBreathing function that returns a score from 0 to 100 according to the breathing pattern chosen by the user. From the experiments conducted it has been observed that to obtain reliable score results it was necessary to carefully choose the hyperparameters. By finetuning these parameters based on recorded breathing we can obtain reliable score results. This study provides an original and innovative approach to breathing support through the use of mobile apps that can be a good basis for future studies.

Since the hyperparameters of the scoreBreathing function have been set on a very small sample (4 boys of the same age, gender and body type) the application is not yet ripe for wide-ranging use. The survey in question should consider users of different age, weight, sex and respiratory capacity. Another aspect that would lead the JustBreathe application to be more precise in judging the user's breathing is to intervene in the signal processing phase, trying to use other filtering techniques or to implement other methods to reduce the noise in the raw signal obtained from the accelerometer.

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