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System to Recommend the Best Place to Live Based on Wellness State of the User Employing the Heart Rate Variability

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ABSTRACT The conditions of the environment where a person lives have a great impact on his wellness state. When buying a new house, it is important to select a place that aids in improving the wellness state of the buyer or, at least, keeps it at the same level. A deficient wellness state implies an increase of stress and the appearance of some effects associated with it. Heart rate variability (HRV) allows measuring the stress or wellness levels of a person by measuring the difference in time between heartbeats. A low HRV is related to high stress levels whereas a high HRV is associated with a high wellness state. In this paper, we present a system that measures the wellness and stress levels of home buyers by employing sensors that measure the HRV. Our system is able to process the data and recommend the best neighborhood to live in considering the wellness state of the buyer. Several tests were performed utilizing different locations. In order to determine the best neighborhood, we have developed an algorithm that assigns different values to the area in accordance with the HRV measures. Results show that the system is effective in providing the recommendation of the place that would allow the person to live with the highest wellness state.

INDEX TERMS Wellness, heart rate variability, heart rate, stress, BigData, real estate.

I. INTRODUCTION

Heart Rate (HR) is a parameter that has been employed for centuries in order to determine the physical condition of a person [1]. Nowadays, HR is employed in a wide range of areas such as medicine, health state, physical training and even to assess the emotions and stress levels of a person [2]–[4]. HR depends on the rate of the sinus node depolarization. This rate is not constant, in fact, the Autonomic Nervous System (ANS) affects the pace of the heartbeat. ANS is composed of the Parasympathetic center and the Sympathetic center. Both centers generate different response from the heart. The Parasympathetic system is employed to decelerate the HR and is associated with a resting state, while the Sympathetic system elevates it and contributes to the states of anxiety, stress and physical exercise [5]. HR allows measuring the number of heart beats per minute. However, this measure has its limitations considering that the information of the cadence of each beat is not regarded. Heart Rate Variability (HRV) is a parameter that measures the time span between beats. This is performed by quantifying the R-R interval, which corresponds to the time between sinus node depolarizations. Besides the time domain, HRV can be assessed in the frequency domain [6]. The low frequency band, associated with a range of frequencies between 0.04Hz and 0.15Hz, is affected by the Parasympathetic and the Sympathetic centers. The high frequency band, corresponding from 0.15Hz to 0.4Hz, is only altered by the Parasympathetic center. Breathing patterns are also an important factor to consider when measuring the HRV [7].

This measure allows identifying a wide range of conditions as there are more variables to define the state of an individual. Firstly, it is an indicator of heart disease or a deterioration of the ability to regulate the HR. Other physical afflictions related to the HR are chronic pain, muscular tightness, inefficient digestion and immune system disorders among others. Secondly, it is an excellent indicator of the physiological stress and the state of the body in order to recover from an exercise session. Low HRV indicates high stress. HRV is highly employed in the sports sector for purposes such as designing a specific exercise session for the current condition of the body [8]. However, HRV is not only an indicator of the physical condition of a person but also an indicator of its psychological state. Variations of the HRV are associated with the emotions experienced by the individual [9], [10]. Negative emotions heighten the appearance of disruptions of the HRV patterns while positive emotions improve the pace of the heartbeats thus, anxiety, depression and insomnia are conditions that decrease the HRV. Finally, and related to the aforementioned disorders, some studies have found the correlation between stress and HRV variations [11], [12]. During stressful cases, HRV presents a low variation as opposed to the regular variations presented when enjoying a peaceful and relaxed state. Consequently, HRV can be employed to monitor the stress levels of a person in order to detect stress triggering situations or environments.

Recently, the awareness in the importance of living a healthy life is increasing significantly [13]. The term Wellness was firstly introduced in the 1950s and is not only related to fitness or physical wellbeing but also with a good psychical and emotional state [14]. According to the National Wellness Institute of the United States, the wellness state of a person can be measured through six dimensions [15]. These dimensions are the emotional, occupational, physical, social, intellectual and spiritual dimensions. Each person may have a different standard to each dimension thus, there is not a specific way of reaching a wellness state as each individual may have different requirements. However, today people are faced in their daily life by a wide range of stressful situations that threatens their wellness state.

Nowadays, stress is being the source of a great number of physical and psychological disorders and it is continuously increasing. In the United States, around 70% of the population experience physical and psychological effects of stress [16]. Fatigue, headaches, disturbed digestions, muscle tension, dizziness and changes in appetite and sexual drive are some of the physical symptoms of stress. Irritability, anxiety and lack of energy, among others, are some of the psychological effects of stress. For many people, a continuous state of stress develops into a depression disorder. OMS estimate that more than 300 million people globally suffer depression [17]. Stress was firstly described as the nonspecific response of the body to any demand. The disorders generated by stress are basically an error in the adaptation process of the body. These errors can be prevented by aiding the adaptation process to improve the perception of a stressful situation or environment.

Several studies have been performed on the correlation between the emotions felt at the place of residence and the stress or wellbeing caused by it [18]–[22]. When people do not feel comfortable at their homes and attach to them negative connotations, their stress levels and health problems increase. On the contrary, a feeling of attachment and a good environment increase the quality of life and the physical and psychological health. Cultural differences, personal preferences and their feelings on the surrounding environment can have an impact on the wellbeing of a resident of the area. Living in a place where the person feels comfortable can help him/her to release their stress and consequently, increase his/her HRV and improve his/her health.

In this paper, we propose a system that helps house buyers to determine the best place to live in accordance with the stress levels measured when visiting the area. Our contribution highlights are:

- Proposal of a system that measures the stress levels of the buyer through HRV by utilizing sensors.
- The employment of a bigdata system to process the obtained data and determine the best place of residence among the visited places for a specific buyer.

As the alarming stress levels suffered globally by the population, we intend to aid in the increase of people living in a state of wellbeing. In order to do that, we have designed a system that allows people to expand their knowledge on the area they want to live in and their psychological response to the place. Our contribution could help many people to increase their wellness but it can also be employed to determine the average stress level that citizens suffer at each neighborhood or city providing a great tool to identify the places were more resources should be invested to increase citizen wellness.

The rest of the paper is organized as follows. Section 2 presents the related work. The system model is presented in section 3. Section 4 depicts the system verification. The measures of the emotional value obtained in the tests are provided in section 5. Final results are presented in Section 6. Finally, the conclusion and future work are included in Section 7.

II. RELATED WORK

The main application of the HRV has been the detection and prevention of cardiovascular disorders. Recently, the utilization of this parameter is being thoroughly studied. Several studies have been performed on stress levels detection. There are several options which can be employed regarding to the length of the measurement, however recent studies prefer to utilize a 5-minute long measure as it allows reducing the cost of executing those metrics. In one of those studies, Castaldo *et al.* [23] utilize ultra-short term HRV to detect the stress levels of college students during an oral examination. They perform linear and non-linear HRV measurements. In order to determine the stress levels, a comparison of the results obtained at the examination with the values measured at holidays is performed. The method employed is a C4,5 tree algorithm and it has a sensitivity of 78%, a specificity of 80% and 79% of accuracy. Moreover, they verify that the stressed subject had lower HRV and non-linear heartbeat dynamics. Munla *et al.* utilize in [24] a 5-minute assessment interval as well. They created a stress level detection system for drivers employing HRV analysis. Their results indicate that there is about 83% of accuracy in predicting stress while employing the Support Vector Machine (SVM) with the Radial Basis Function (RBF) (SVM-RBF) classifier. The presented architecture consists of three phases identified as data analysis, feature extraction, where one of the available domain analyses is utilized, and classification, which determines if the subject is in a stressed or normal situation. Other studies utilize the stress detection to detect office-syndrome. Reenaree *et al.* [25] employ wearable low-cost sensors to measure HRV for the aforementioned purposes. They make use of a pulse sensor on the wrist to detect the HRV instead of the usual chest-strap monitor.

HRV is a very versatile measure and it can be employed for many other usages. Al-Libawy *et al.* [26] utilize a low-cost wearable sensor to measure fatigue levels in operators by using HRV. The employed devices are a chest-strap, a heart monitor and a watch. They use two machine learning algorithms in order to detect if the operator is in a state of alertness or fatigue. A 5-minute measurement period is employed as well. By utilizing the SVM approach, they obtained about 97.2% of accuracy in alertness and 91.3% in fatigue detection. Many of the usages are performed for medical purposes. In [27], Higher Order Spectrum HRV is employed to detect sleep apnea in patients. They proposed the classifier IS-SVM, achieving 90.21%, 86.21% and 88.21% on sensitivity, specificity and accuracy respectively.

Because of the large quantity of data analyzed by health applications, Jindal *et al.* [28] propose a Big Data analytics scheme based on an efficient fuzzy rule in order to implement Healthcare-as-a-service. Diallo *et al.* [29] create a query processing mechanism for wireless body area networks so as to be able to manage a large quantity of data. Their proposal is able to minimize the energy consumption and reduce the query latency.

Many of the studies on HRV are centered on detection and monitoring of illnesses, both physical and psychological. However, our system is centered on improving the wellness by detecting the wellbeing level of the individual in a particular area of the city.

The purchase-sale behavior of the market can be affected by multiple factors. Recently, real state bubbles have burst throughout the world and some countries have started to attain a satisfactory growth rate. Economic studies on real state bubbles show there may be several reasons of the development of a bubble. Kho *et al.* [30] discuss the collapse of the real state price in Asia in the 1990s. They allege it was produced by a peak in underpricing due to lenders. Because of these bubbles, an effort has been made in order to detect possible new bubbles. Zhou and Sornette [31] analyze the real state bubble that occurred in the US between 2000 and 2003 and propose a method to identify bubbles by measuring unstable growth rate increases and comparing it with indicators of previous bubbles. However, Zhou and Sornette [32] determined that possible upcoming bubbles can be detected by verifying if the housing prices growth rate is growing at a faster-than-exponential rate. These studies allow determining the behavior of the market and the factors that affect it. Deng *et al.* [33] test the volatility of house prices in China employing high-frequency unit price data. The Chinese house market was evaluated to determine the existence of susceptibility to the development of bubbles, concluding that the market volatility was due to factors such as rent growth and land supply.

Although the market is a determinant factor in purchase-sale transactions, there are other factors which are intrinsic to the buyers. Koklič *et al.* study in [34] the behavior of house-buyers from their perspective. They introduce a conceptual model of the buying behavior, identify the factors that condition the decision-making process and apply their knowledge to find the benefits of prefabricated houses. They discover that cognitive and rational factors are not decisive in purchasing houses. They also conclude that subjective factors such as environment, feelings, experience or subconscious factors should be considered. Distress can also be related to the time expended in selling or buying a house. Selcuk [35] discusses that the longer a seller is unable to sell his/her property, the more distressed he would be. He proposes an equilibrium search model for specific market conditions. It is designed for periods where sellers are in a distressed state because of the impossibility to sell. Consequentially, house prices drop. At the moment, the most employed measurement is the average time in the market. However, the author proposes to employ the profit loss in fire sales as a more accurate statistic.

We have developed a wellbeing monitoring system that employs HRV measures to determine the best place to purchase according to the feelings of the buyer. It has allowed us to improve the knowledge of the determining factors that affect the buyer in the decision-making and as a form of aiding the buyer to be aware of his/her wellbeing state at the places that are being in consideration for purchase.

III. SYSTEM MODEL

In this section, several aspects will be presented. At first, the system operation will be detailed. Then, the topology and message exchange will be presented. Finally, the characteristics of the employed devices will be specified.

A. EQUIPMENT SPECIFICATION

In order to take the HRV measures, we have employed the Polar V800 wristband. The model was analyzed in [36] in order to assess the validity and reliability of the HRV data.

Polar V800 has a 350mAh Li-pol rechargeable battery. The duration of the battery depends on the measuring mode. It lasts 13 hours with high accuracy GPS (1s of accuracy) recording and heart rate, 20 hours with medium accuracy GPS (30s of accuracy) recording and Heart rate, 50 hours with GPS power save mode (60s of accuracy) and heart rate, 100 hours with the GPS recording disabled and the heart rate measurements enabled and approximately 30 days in time mode. The operating temperature ranges from $-10°C$ to $50°C$. Temperatures below freezing can have a negative impact on the operating time. The manufacturers advise wearing the device under some clothing layers to improve the operating time under below freezing weather conditions.

The accuracy of the device is better than ±0.5 seconds/day at 25°C. The GPS accuracy is ±2% for distance and ±2 Km/h for speed. The altitude resolution is 1m and the ascent/descent resolution is 5m. The maximum altitude is 9000m. It is water resistant up to 30 meters.

Polar V800 is accompanied with the H7 heart rate sensor. It gives precise information of the heart rate of the user. Its accuracy is ±1% or 1bpm. The measurements range from 15 bpm to 240 bpm. It has a battery life of 200 hours and it is water resistant as well (up to 30m). The type of the battery is a CR 2025.

The device allows recording R-R intervals. Those are the intervals between successive heartbeats. Heart rate varies in every heartbeat. HRV is the variation of RR intervals. The device show the result including the duration, start time, end time, minimum heart rate, maximum heart rate and average heart rate. The recordings can be synced to a web service that allows exporting the measures to other applications in order to be analyzed. In this case, the measures are exported to the BigData repository where our algorithms process the information and provide the recommendation of the neighborhood.

The wellness factor is the baseline of our system and the one that determines the feelings of the user at a neighborhood. In order to measure this factor, the following steps were performed [37]:

- Firstly, a 60-second HRV baseline measure is performed every morning at the awakening moment. It is better to gather measurements for at least one week in order to establish a more accurate baseline. The user should breathe deeply and be in a relaxed position at the moment of the measure. Anxiety could affect the measure itself [11], [38]–[41]. Because of that, the stress level is measured by the variability regarding the HRV baseline.
- Secondly, each measurement performed throughout the day is compared with the personal baseline in order to establish the emotional factor at a neighborhood. The wristband should be worn for the complete duration of the visit to a neighborhood.
- The emotional factor can range from a normal state, where the user is not feeling stressed, to medium or high stress levels. An upward trend in the HRV signals that the user is enjoying the neighborhood. On the contrary, HRV values decrease when there is stress.
- Lastly, long-term indicators aid in identifying the places or neighborhoods less indicated for the user.

If there is a significant difference regarding the baseline, a positive or negative value is established for the emotional wellbeing concerning the considered neighborhood. An accumulative state is calculated to decide whether the neighborhood presents a positive or a negative effect on the user. The neighborhood value is set to zero at the beginning of the measurement.

In order to calculate the limits of the neighborhood, the x, y and z positions are established on the GPS. That should be done to introduce in the system all the desired neighborhoods. The HRV is calculated for each established time span, which is defined by the system. The time spent at each area is employed to calculate the pondered value for each neighborhood.

B. SYSTEM OPERATION

In order to select the best profile for a user, several factors are considered. Firstly, factor x is assessed by user established parameters. The order of preference among the neighborhoods of the city, price and evolution of the state of the market comprise those parameters. Secondly, another factor evaluates for each week the Convenience Factor estimated by the wellbeing state measured by the HRV analysis, and the time the user spends at each neighborhood. The operation of the aforementioned factors is described in the algorithms presented in Fig. 1.

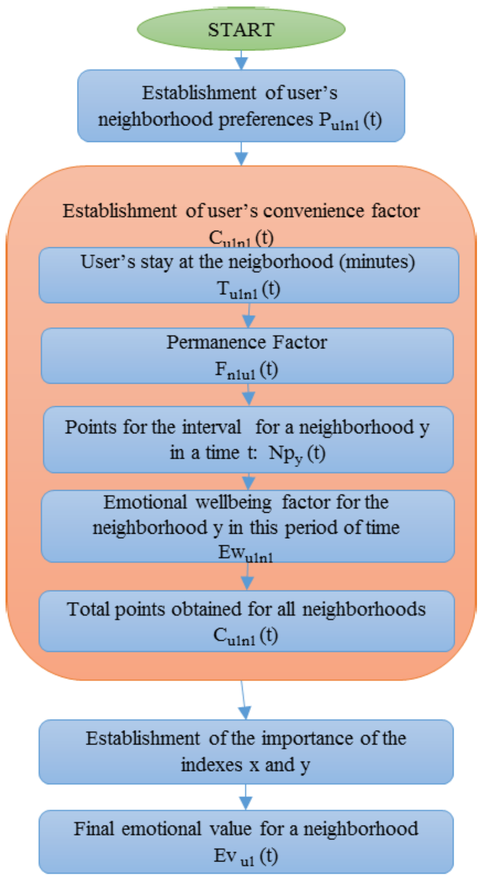

FIGURE 1. System algorithm.

In order to measure the Final Wellness Value of a neighborhood, the priorities of the user for each area must be determined. The priorities are composed by the importance factor assigned by the user to his/her preferences and the importance factor applied to the data obtained by the system, also known as the Convenience Factor.

The user registers his/her R-R intervals every day. The first time the HRV is evaluated, the R-R measures obtained when rising from bed is employed. It is the time when the body presents lowest stress levels. That avoids obtaining a measure affected by the stress factors the user encounters throughout the day. The result is the HRV baseline.

The Convenience Factor for a specific neighborhood is calculated analyzing the time the user spends at the area and measuring the HRV values of the user for that period of time. The Convenience Factor, designated as C_{u1n1} (t), is the addition of the points obtained at a neighborhood which depend on the weekly time of permanence at the neighborhood, T_{u1n1} (t), the Permanence Factor $Fn1_{u1}$ (t), and the Emotional Wellbeing Factor attained at a specific neighborhood, Ew_{u1n1} (t). The *interval_time* is the amount of time the user spends at the neighborhood.

$$Fn1_{u1}(t) = T_{u1n1}(t)/interval\_time \quad (1)$$

Once the time and the HRV are computed, the result is compared with the HRV baseline. The relation between the variation of the HRV in a neighborhood and the HRV baseline, as well as the time spent in the area, is employed to assign positive or negative points to that neighborhood. Consecutively, the number of obtained points is multiplied by the permanence ratio of the neighborhood regarding the period established for calculating the new HRV value. Thereupon, the points of each neighborhood will increase or decrease in accordance to the HRV values obtained when the user was physically present in the area.

The emotional wellbeing factor for a neighborhood at a specific time is designated as Ew_{u1n1} (t). $Np_y(t)$ is the points for an interval for the neighborhood y in a time t.

$$Ew_{u1n1}(t) = F_{n1u1}(t) * Np_y(t) \quad (2)$$

The total of the points obtained for a neighborhood is presented as C_{u1n1} (t).

$$Cu1n1\ (t) = \sum Ewu1n1(t) \quad (3)$$

The Final Wellness Value, Ev_{u1} (t), is composed by the preference factor of the user, P_{u1} (t), the convenience factor of the user, C_{u1} (t), and the importance indexes assessed by x and y, $x + y = 1$. The calculation for the Final Convenience Factor for the neighborhood is performed dividing the points obtained by the user for a neighborhood by the amount measured for all the neighborhoods. Final Convenience Factor is employed to determine the Final Wellness Value for the neighborhood, which considers the user's preference factors.

$$Ev_{u1}(t) = x * P_{u1}(t) + y * C_{u1}(t) \quad (4)$$

Fig. 2 presents the method of measurement of the points for each neighborhood regarding the evolution of the HRV. Every morning at the awakening moment, a measure of HRV is taken under no stress conditions (HRV baseline measurement). In order to calculate the HRV score it is necessary to obtain the R-R interval values of the user. After that, the RMSSD (Root Mean Square of Successive Differences) is established. Then, the ln(RMSSD) is calculated to obtain a number that behaves in a more linearly distributed fashion. The ln(RMSSD) is expanded to generate a final score. Along the day, some other HRV measurements are estimated.

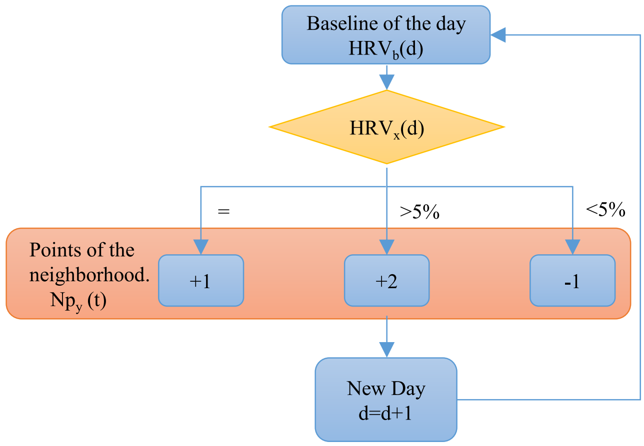

FIGURE 2. **Neighborhood points for a time span.**

The values estimated are considered as normal when the measure ranges from 5% above the baseline to 5% below the baseline [42], [43].

$$\begin{cases} \text{if } HRVx(d) = (HRVb(d) \pm HRVb(d)^{*}0,05) \rightarrow \\ \qquad Npy(t+1)) = (Npy(t)) + 1 \\ \text{if } HRVx(d) > (HRVb(d) + HRVb(d)^{*}0,05) \rightarrow \\ \qquad Npy(t+1)) = (Npy(t)) + 2 \\ \text{if } HRVx(d) < (HRVb(d)HRVb(d)^{*}0,05) \rightarrow \\ \qquad Npy(t+1)) = (Npy(t)) - 1 \end{cases} \quad (5)$$

If the reading is significantly low after the first day in contrast to the baseline, there is a presence of low levels of stress and the state is computed as −1. If the state is continued for a second day a −2 value is computed. A −2 value is computed as well for a suddenly lowered heart rate followed by an unusually high HRV. When the daily value is similar to the average, the computed value is +1. If it is significantly high compared to the baseline, it is computed as +2.

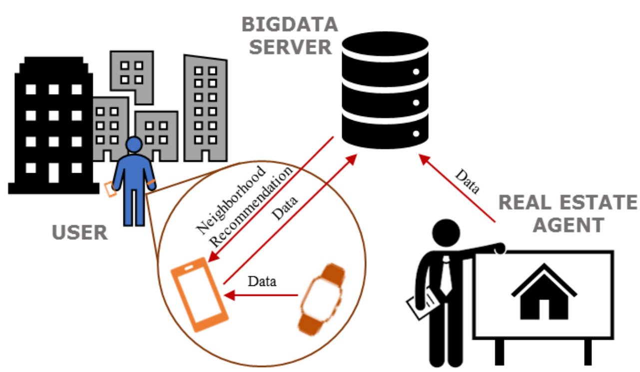

FIGURE 3. **Topology of the system.**

C. TOPOLOGY AND MESSAGE EXCHANGE

The topology of the system is displayed in Fig. 3. The data obtained from the wristband is forwarded to the mobile device. The device updates the data on the BigData repository. The Real Estate agent updates the houses information at the same BigData repository from the device. The BigData server informs the user about the Final Wellness Factors and recommends a preference order when searching and selecting houses to purchase or rent.

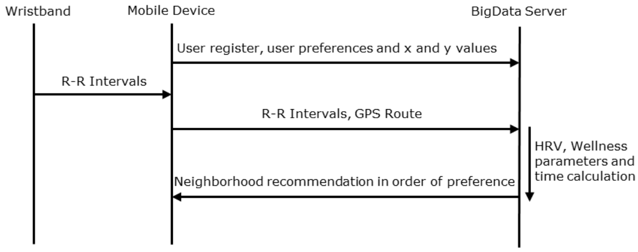

FIGURE 4. Exchange message between the devices and the server.

The exchanged messages are shown in Fig. 4. When the user logs in the system, the values related to the Preference and Convenience Factors are forwarded. The R-R intervals are measured from the wristband of the user. The GPS data are obtained from the mobile phone of the user. Then, the aforementioned information is submitted to the BigData server in order to process it. Consecutively, the server calculates the HRV values and the points for each neighborhood. Moreover, the obtained neighborhood priority is computed regarding the preferences of the user and the obtained data. Fig. 5 shows the messages exchanged between the Real Estate agent and the Server. Firstly, the Real Estate agent must be logged. Then, the available houses can be uploaded on the server. Finally, the server acknowledges the upload.

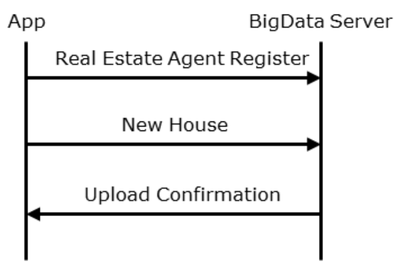

FIGURE 5. Exchanged messages between the App and the server.

IV. SYSTEM VERIFICATION

In this section, the system verification is performed by employing real measures. Table 1 depicts the establishment of the Convenience Factor of the user. Firstly, the HRV baseline is measured in order to determine the state of the user when being relaxed. Secondly, two sets of measures are performed at two different times and in different places. The HRV value measured at 10:00 was 30 and the value measured at 11:00 was 37. The established points are then selected comparing the HRV value obtained at the neighborhood and the HRV value of the baseline. The established point for the first measure is −1 because its HRV measurement is below the baseline. The established point of the second measure is +1 because the HRV is above the baseline. When starting the measurements, all initial values of the neighborhoods are set to 0. The time spent at each location was 45 minutes at San Julián (1st place), 15 minutes at San León (2nd place) and 60 minutes at Ensanche (3rd place). Each time is then normalized resulting in the values of the interval time, being 0.75, 0.25 and 1 respectively. After collecting the aforementioned information, the neighborhood value is calculated. The values are −0.75 for San Julián, −0.25 for San León and 1 for Ensanche.

TABLE 1. Establishment of the convenience factor of the user.

HRV baseline	34			
	First measurements at 10:00		**Second measurements at 11:00**	
HRV measurement	30		37	
Established points	-1		2	
Initial values:	**San Julián**	0	**Fuenfresca**	-0.25
	Fuenfresca	0		
Visited Neighborhoods:	**San Julián**	180 minutes	**Fuenfresca**	240 minutes
	Fuenfresca	60 minutes		
Interval time:	**San Julián**	180/240=0.75	**Interval time Fuenfresca**	240/240 =1
	San León	60/240= 0.25		
Neighborhood value:	**San Julián**	-1*0.75= -0.75	**Neighborhoo d value:**	1*2= 2
	Fuenfrescas	-1*0.25= -0.25	**Final Neighborhood value (Fuenfresca):-0.25+2= 1.75**	

TABLE 2. User points obtained for each neighborhood and their weighting value.

User points		**Weighting value**
San Julian	5	0,33
San León	2	0,11
Centro	-1	-0,06
Fuenfresca	7	0,39
Ensanche	3	0,17
Total	18	

The system is able to consider the values of other users and it employs them in order to obtain a more precise value. Table 2 depicts the establishment of the convenience factor of other users. The final recommended value combines the information of the neighborhood value of the user, 1, and the neighborhood value in average, 4. Those values are modified by two factors. The x factor ponders the user value and it is set to 0.75. The y factor ponders the average value of other users and it is set to 0.25. Overall, the recommended value is 1.75.

So as to determine each location, a neighborhood coordinate establishment was performed employing [44]. A neighborhood is determined setting the coordinates of several

FIGURE 6. Points limiting Fuenfresca neighborhood.

points placed on the limit of the area. As it is shown in Fig. 6, each point is represented by its latitude and longitude, which allows delimiting each measured areas in the system.

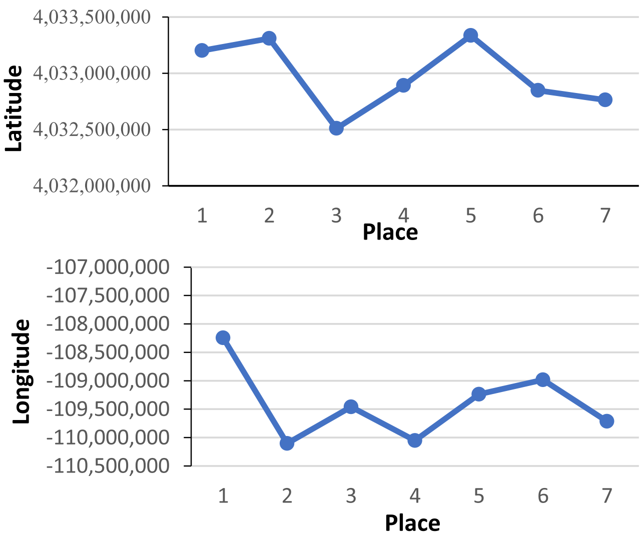

FIGURE 7. Latitude and longitude of the points limiting Fuenfresca neighborhood.

Fig. 7 presents the latitude and longitude of the points limiting the neighborhood. The system was tested in several areas and the process of defining the neighborhood was performed for each of them.

The rest of the neighborhoods employed to test the system are presented in Fig. 8. As it can be seen, the selected areas have different characteristics. Some of them have services such as parks and sports fields, while the others do not. The number of points employed in defining the neighborhood varies in accordance with the characteristics of each area.

Hereafter, an example of a registered route made by a user is presented. In order to establish significant times, a neighborhood only is considered if the user spends more than twenty minutes at the neighborhood. Fig. 9 shows the route from the starting point of Calle Sta. Amalia, 3, 44003 Teruel, España, to the destination, Calle los Tilos, 1, 44002 Teruel, España. The latitude and longitude of the coordinates

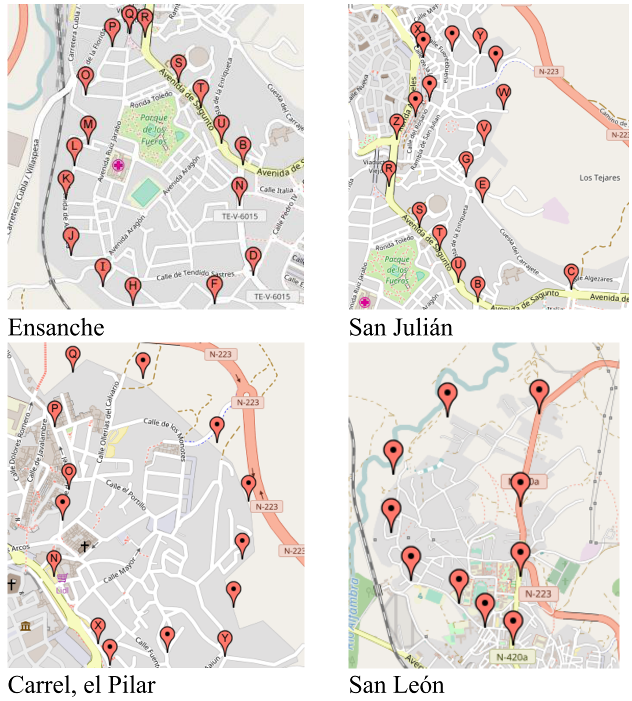

FIGURE 8. Neighborhoods employed to test the system.

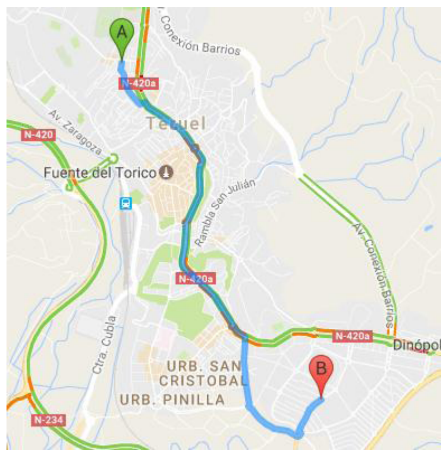

FIGURE 9. Route performed by the user.

measured throughout the route are presented in Fig. 10. It uses WGS84 geodetic datum in decimal form.

V. MEASUREMENTS OF THE EMOTIONAL VALUE

In this section, the results obtained for the different parts of the process for evaluating the emotional value of a neighborhood are presented. Fig. 11 presents the evolution of the heart rate throughout the measure time and the HRV for the same time. Comparing both graphs it can be concluded that significant drops in heart rate are tied to an increment of the HRV. Also, a stable HR measure does not imply a stable HRV as shown in Fig. 11 from minute 450 to minute 900.

When considering the real movements of the user with the time he/she stayed at each neighborhood we obtain the results

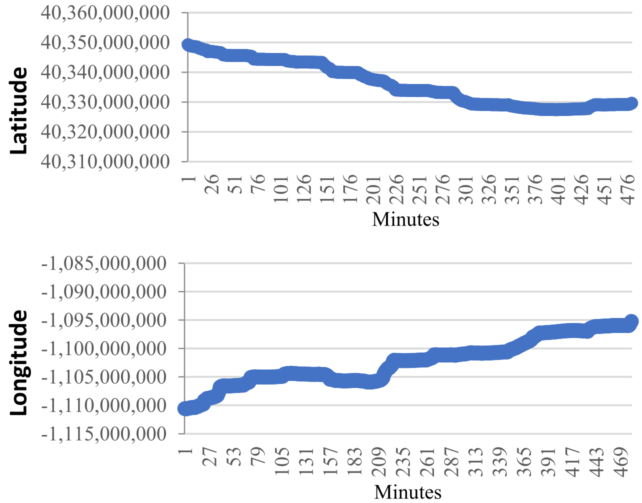

FIGURE 10. Latitude and longitude throughout the route.

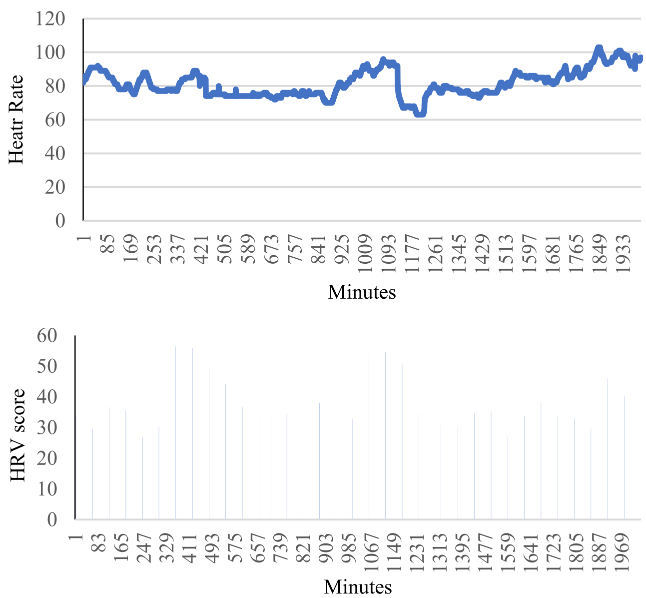

FIGURE 11. HR (beats per minute) and HRV throughout the measurement time.

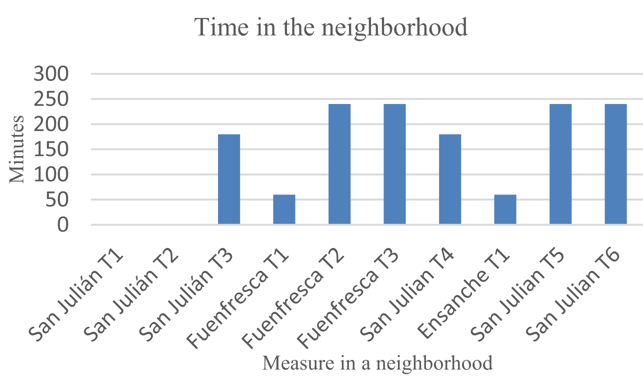

FIGURE 12. Expended time in the neighborhoods.

shown in Fig. 12. We can also see the final emotional points obtained for each area. In Fig. 13 the number preceding the name of the neighborhood is the HRV measure. The measures

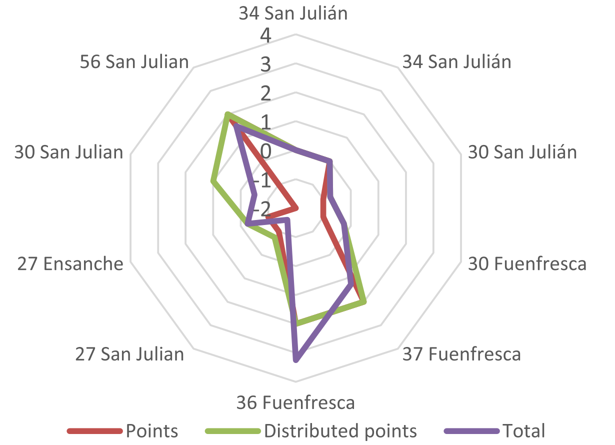

FIGURE 13. Points throughout each neighborhood.

are performed periodically, thus, there may be more than one measure for the same neighborhood. Fig. 13 displays the measurements. The red line marks the points obtained for the area. The green line shows the distributed points and the purple one displays the final points that are going to be considered by the application. The total points are obtained adding the distributed points of the same neighborhood as the measure progresses.

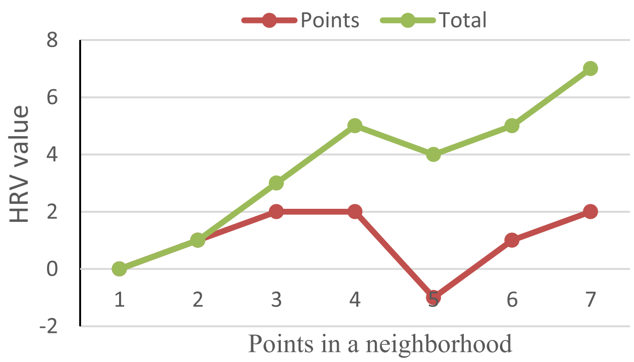

FIGURE 14. Evolution of the points throughout the neighborhoods.

The evolution of the points for each neighborhood is presented in Fig. 14. Each number represents a measure of the HRV. When there are positive values, the points are added to the neighborhood, for negative values, points are deducted. The name of the same neighborhood is displayed as many times as measures have been performed. Thus, the result is different from the first assessment. The total is the addition of all the points obtained for the neighborhood and it can be affected by the preference factors.

Fig. 15 displays the evolution of the HRV values for the same measurements used in Fig. 14. The higher the HRV score the less stressed the user is. The similarity between the points and the HRV measures is very high. When the user is feeling less stressed, the points assigned to the neighborhood increase.

VI. RESULTS OF THE NEIGHBORHOOD VALUE

The results for the final neighborhood value obtained for an example test are presented in this section. Table 2 shows

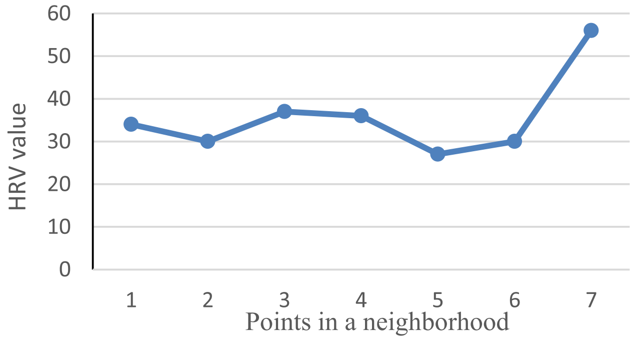

FIGURE 15. Evolution of the HRV score throughout the neighborhoods.

the user points for each neighborhood and their weighting value. Fuenfresca has the highest mark, 7, followed by San Julián and Ensanche. The worst score belongs to Centro. The weighting values for this case range from −0.6 to 0.39.

TABLE 3. Preference factor of the user.

	Points	Weighting value
San Julian	0	0
San León	0	0
Centro	6	0,6
Fuenfresca	8	0,8
Ensanche	10	1

The first step in the measuring process is to establish the Preference Factor of the user. Preference must be evaluated by the user and it ranges from 0 to 10, being 10 the highest preference and 0 the lowest. Table 3 shows the values obtained for this test. Then, the weighting value is set employing a range from 0 to 1. Through the data, the system is able to know that the user prefers Ensanche, followed by Fuenfresca and Centro.

TABLE 4. User evaluation of the parameters for preference and convenience value.

Preferences			Total score	Convenience factor			Total score
Considerable		10		**Considerable**	x	10	1
Enough		8		**Enough**		8	
Neutral		6		**Neutral**		6	
Regular	x	4	0,4	**Regular**		4	
Slight		2		**Slight**		2	
Nothing		0		**Nothing**		0	

The next step is to find the opinion of the user about the importance of his/her priorities or the convenience value. In order to do so, the user is asked to evaluate from 0 to 10, being 10 the highest importance and 0 the lowest, the importance each parameter has in his/her opinion. Table 4 shows the user evaluation for the parameters x and y. This user preferred the convenience factor to his/her preferences on each neighborhood. Thus, the value for preferences is 4, resulting a Weighting Factor of 0.4, and the value for the Convenience Factor is 10, resulting in a Weighting Factor of 1.

TABLE 5. System recommendation on each neighborhood.

Final values	
San Julian	0,28
San León	0,11
Centro	0,18
Fuenfresca	**0,71**
Ensanche	0,57

From the aforementioned data, the final emotional values can be obtained. The algorithm presented in Fig. 1 is employed to determine these values, which are presented in Table 5. As shown, the recommended neighborhood for the user is Fuenfresca, as it has the highest value. The second-best option is Enchanche and the worst one is San León.

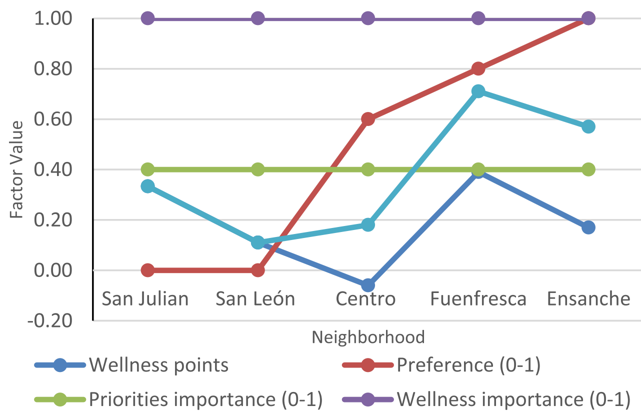

FIGURE 16. Compilation of the results of the test.

Fig. 16 presents a compilation of the aforementioned values. As it can be seen, the wellness points affect greatly the final results. For both, the wellness points and the final recommendation, the neighborhood with the bigger amount of points is Fuenfresca. The preference is also very important. Neighborhoods with low preference values such as San Julián and San León will not be recommended due to that factor. However, neighborhoods with high preference values, such as Centro, may not have a high final value. These results show that our system provides the best recommendation in accordance to the wellness values. Moreover, what the users think is best for them may not be the best for their wellness.

VII. CONCLUSION

A system that determines the living place best suited for a user in order to enjoy a high level of wellness has been presented. By measuring the HRV differences and using BigData we have been able to determine the wellness factor of the user for each visited neighborhood. This aids to the wellbeing of the buyer allowing deciding the place where the external factors affect the user the least, resulting in low stress levels due to said factors. Our tests show the effectiveness of our system providing the best recommendation for each user.

Other factors such as the maximum price, the amount of money the buyer is willing to pay and the time that he/she can wait to purchase the house are going to be considered in future works. This allows the system to avoid the recommendation of an area where the user cannot afford a house. We would also like to link the system to real state webpages in order to expand the information of the average wellbeing value and to be able to recommend other available houses to the user when the buyer is not satisfied with the visited houses. Moreover, other indoor positioning systems will be added in order to have an accurate position when GPS is not working [45], [46].

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