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Automation of Interventional Analysis in Physiological Variability Using Data Mining: A Review

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Abstract: The changes or variations that occur in physiological parameters of the body when a person is in state of rest, which means he/she is still, lying down, not talking, not under any pressure not even thinking, if possible, is termed as physiological variability (PV). The importance of physiological variability was realised thousands years ago by Indian Medical System, AYURVEDA. It was then referred as “NAADI PARIKSHA”. Today, the Interventional analysis of physiological variability had become crucial for the assessment of Autonomic Nervous System(ANS) activities. ANSis further divided into Sympathetic and Para-Sympathetic Systems which have opposite impact on any of the organ systems of an individual. Increase in the heart rate, the secretions of the glands of alimentary track etc. are some physiological factors controlled by ANS. This paper discusses various research papers and articles, analysing how the factors determining the physiological ari ability can be easily calculated by intervening with the body only non-invasively in order to determine the individual’s health index. Emphasis have also been laid on increasing number of softwares used for analysis of such data; where the developers use various Data Mining Techniques for developing such medically relevant softwares. Heart Rate Variability (HRV), Peripheral Blood Flow Variability (PBFRV) and Morphological Index Variability (MIV) are the main highlights as these are key parameters in PV.

Keywords: Physiological Variability, Automatic Nervous System, Para-Sympathetic Changes, Data Mining.

I. INTRODUCTION

Suppose a person walking on the road suddenly sees a snake passing nearby. What will happen? The heart beat would suddenly increase! ;when the snake goes away, the heart beat would again turn to normal gradually. These obvious changes observed during the emergency situation continue to take place within the body at a much lower level, even otherwise, even when the person is lying down quietly; without his knowledge. The changes brought by these mechanisms in the body function in resting state are termed as physiological variability[10].

In Indian Ayurvedic System, the physiological variability had the subjective method for analysis of physiological variability known as “NAADI PAREEKSHA”, used to assess the health index of an individual. In this method, three positions were palpated by Ayurvedic physicians at wrist location of the patient; and mentally monitoring of the rhythm was done; pulse volume, pulse propagation & pulse pressure etc were calculated whose outcome depended on the subjective bias.
Several mechanisms control the physiological variability in human beings such as Sleep, rennin-angiotens in system, thermo-regulation, baro-receptor reflex and ANS. Mechanisms other than ANS cause long term variations whereas ANS is responsible for short term variations in the physiological variability’s beared by an individual. Autonomic activity is initiated at levels of the brain below cerebrum implying that the activity does not get stimulated voluntarily i.e. it gets stimulated involuntarily. Autonomic Nervous System is responsible for variations in heart rate, rate and force of heartbeat, etc. It affects the working of internal body organs.

ANS has task of increasing or decreasing the activity of particular system and had been divided into two parts:
a) Sympathetic Nervous System(SNS)
b) Para-Sympathetic Nervous System(P-SNS)

Sympathetic system increases the activity of a particular organ, while, the para-sympathetic decreases the activity of the same and vice versa. SNS stimulate body’s fight or flight response on seeing danger while P-SNS is responsible for rest and digest. It brings the body to normal state.

1.2 Factors Affecting Physiological Variability:

Functioning of the living body is better explained with the help of physiological parameters. These parameters can be measured either non-invasively or invasively.

- Some of the most common examples are Heart Rate, Body Temperature, Blood Pressure and Respiration Rate.
- Stroke output, peripheral blood flow, peristalsis of intestines, secretion of endocrinal and salivary glands, glycogen-glucose conversion, secretion of urine,motility of large and small intestines, etc. are other physiological parameters better known to the medical community.

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- Some of these like heart rate, respiration rate and blood pressure can be easily measured for long time interval without causing any harm or discomfort to the patient.

Typical frequency spectrum of Heart Rate Variability (HRV) is shown in Figure-1, comprising LF, MF and HF peaks and can numerically be represented by 11 parameters listed in Table-I.

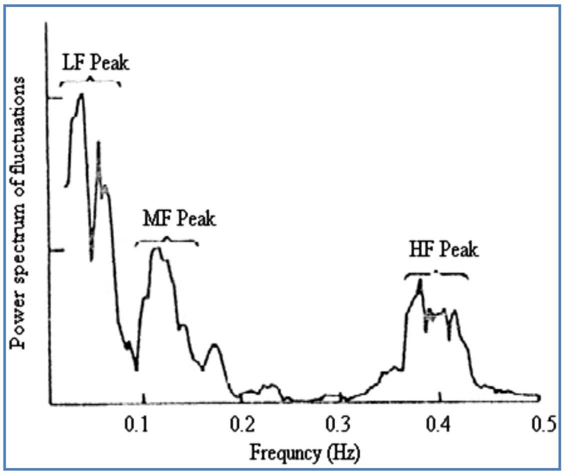

Fig 1: power/frequency spectrum of heart rate fluctuations [10]

Similar parameters are also available for Peripheral Blood Flow and Morphological Index, which are prefixed with PBF and MI respectively in place of HR.

Table-I: NUMERICAL REPRESENTATION OF LF, MF ANDHF PEAKS

S.No	Parameter	Description
1.	HRV_TP	total power of fluctuations
2.	RR_MEAN	mean time interval between consecutive R waves in ECG
3.	HRV_LF_PA	low frequency peak amplitude
4.	HRV_LF_F	central frequency of low frequency peak
5.	HRV_LF_A	area under low frequency peak
6.	HRV_MF_PA	medium frequency peak amplitude
7.	HRV_MF_F	central frequency of mid frequency peak
8.	HRV_MF_A	area under medium frequency peak
9.	HRV_HF_PA	high frequency peak amplitude
10.	HRV_HF_F	central frequency of high frequency peak
11.	HRV_HF_A	area under high frequency peak

Physiological variability ishighly sensitive to reveal instantaneous changes in the body. Therefore, it has lot of random variations which can be termed as noise. Changes produced in the body by medical intervention (administration of medicine) are smaller than the random noise. To detect interventional information in the presence of noise statistical or graphical methods are used. The former improves signal to noise ratio but decreases the sensitivity of the method, whereas the latter introduces subjective bias.

Data mining is the process of extracting useful information from the huge raw data. It is proposed to use data mining techniques to extract interventional information without losing the sensitivity of the method or introduction of subjective bias[16].

II. LITERATURE REVIEW

A. Automatic Prediction of Cardiovascular and Cerebrovascular Events Using Heart Rate Variability Analysis[1]

According to P. Melillo, R. Izzo, A. Orrico, P. Scala, M. Attanasio, M. Mirra, N. De Luca and L. Pecchia, development of novel predictive models using pre – existing data mining algorithms for providing an automatic risk stratification tool for hypertensive patients. The predictive model designed was based on random forest and identified hypertensive patients with sensitivity rate as high as 71.4% and specificity as 87.8%. Hence , we conclude that parameters of Heart Rate Variability can be used to detect future vascular events and for identifying hypertensive patients.

B. Heart Rate Variability: New Perspectives On Physiological Mechanisms, Assessment Of Self-Regulatory Capacity, And Health Risk[2]

Rollin McCraty, Fred Shaffer, say that Heart rate variability i.e. the rate of time intervals between adjacent heartbeats, is a prominent property of interdependent regulatory systems that operates on different time scales to adapt to environmental and psychological challenges. This article reviews neural regulation of the heart and offers some new perspectives on mechanisms underlying the very low frequency rhythm of heart rate variability. It has been discussed how the heart rate variability rhythms are interpreted in context of health risk, physiological and psychological self-regulatory capacity assessment. Heart rate and blood pressure are adjusted through sympathetic and Para-sympathetic efferent pathways by cardiovascular regulatory centred in spinal cord and medulla integrating inputs from higher brain centre with afferent cardiovascular system. It has also been discussed that the activities in the sub cortical, front cortical, and motor cortex areas by afferent information obtained through the intrinsic cardiac nervous system and the heart-brain connection pathways. In addition, review of the use of real-time HRV feedback to increase self-regulatory capacity is done. It was concluded that both physiological and psychological functional status of these internal self-regulatory systems are reflected by complexity and stability of heart's rhythms over longer time scales.

C. Early Detection of Coronary Heart Disease Using Peripheral Pulse Analyzer[3]

J. Warrier, A. Deshpande, P. Athavale, U. Bagal, M. Rajput and G. Jindal presented in this paper that the principle of Impedance Plethymography is used by Peripheral Pulse Analyzer (PPA) . PPA has been used for early detection of coronary heart disease by measuring electrical impedance and its time derivative which represents blood flow at three consecutive parts on the wrist of the human-being. About 300 control subjects have been used for analysing peripheral plethysmogram from the chest. They have deduced eight dominant morphological patterns of peripheral pulses in control subjects depending on their health status. In cognizance with these observations, A Fourier transform based method has been developed and integrated with PPA to obtain peripheral pulse's morphological index. The index varies from 0 to 1, where 0 indicates the poorest and 1 the complete health. These observations were verified by variability spectrum of heart rate and peripheral blood flow. The patients with myocardial Infarction were observed to have average MI as 0.3. The early stages of the coronary artery disease were found to be 0.4. Hence it was concluded that coronary artery disease can be detected in early stages.

D.Enabling the integration of clinical event and physiological data for real-time and retrospective analysis[4]

In this paper, J. Percival, C. McGregor, N. Percival and A. James presented prototype architecture for both a real-time mobile clinical event data capture application and an Artemis-based replay system for retrospective analysis and validation of physiological data analytics[5]. Also they have identified the new scopes of mobile applications through increased security, robustness, integration into analysis using data mining and future clinical support algorithms.

E. A comparative analysis of classification techniques on medical data sets[5]

Pooja Mittal, Nasib Singh Gill says that data mining classification technique handles many of the problems including diagnoses, ananlys is and responsiveness of medicines. In this paper they have presented the comparative analysis of data mining techniques and showed the great scope of developing new data mining algorithms for medical data classification and directs towards future research.

F. Data Mining for Wearable Sensors in Health Monitoring Systems: A Review of Recent Trends and Challenges[6]

According to HadiBanaee, Mobyen Uddin Ahmed and Amy Loutfi, the wearable sensors available in the market are used for physiological monitoring of vital signs produced by human body. The data collected and processed have to mine in order to find effective results. Also they have outlined various challenges faced by data mining methods in health monitoring systems.

G. Parallel support vector architectures for taxonomy of radial pulse morphology[7]

S. H. Karamchandani , U. B. Desai, S. N. Merchant, G. D. Jindal have presented represented the application of impedance plethysmography (IP) for impedance measurement. Impedance measurement is the paradigm in assessment of central and peripheral blood flow[8]. Multiclass pattern recognition problem uses diverse parallel support vector machine (pSVM) where PCA-based pSVM classifier offers a comparatively higher generalized correlation coefficient and κ value of 0.6586 and 0.8407 respectively.

H. An Exploratory Study on Scientific Investigations in Homeopathy Using Medical Analyzer[8]

Nirupama Mishra, K. CharanMuraleedharan, MD(Homoeo), Akalpita Sriniwas Paranjpe, PhD, Devendra Kumar Munta, MD(Homoeo), Hari Singh, BSc(Hon), DHMS, and Chaturbhuja say that their objective was to observe the action of homeopathic medicines on physiological variability of blood flow and heart rate. Various medicines like Aconitum napellus produced a response in blood flow variability with 1M potency and in heart rate variability (HRV) with 30c potency. Sulphur 200c and 1M, Gelsemium 200c and Pulsatilla 200c, produced a 62.5% response in HRV against the placebo response of 16.6%. Gelsemium, Phosphorus, and Sulphur produced a response in blood flow variability with a 1M potency, similar to the response of Aconitum napellus1M[8]. Hence it was concluded that the response of homeopathic medicines on physiological parameters of ANS can be recorded.

I. Nonlinear Heart Rate Variability features for real-life stress detection. Case study: students under stress due to university examination [9]

F. Melillo, M. Bracale and L. Pecchiainvestigated heart rate variability due to stress and proposed a classifier based on non-linear features of HRV for automatic stress detection. They used linear Discriminant Analysis(LDA) for development of classifier. LDA generated a simple classifier based on the two Poincaré Plot parameters and Approximate Entropy, which enables stress detection with a total classification accuracy, a sensitivity and a specificity rate of 90%, 86%, and 95% respectively[9].

J. A Handbook on Physiological Variability, edited by G.D. Jindal, K.K. Deepak &R.K.Jain[10]. Advanced Applications of Physiological Variability is a handbook published by scientists of Bhabha Atomic Research Centre(BARC) and Physiologist of All India Institute of Medical Sciences (AIIMS) and include interesting chapters about prominent inventions and discoveries made in the field of analysis of physiological variability. It gives

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wide ideas about techniques of measuring physiological variability, its clinical applications, protocols for recording short term variability in physiological signals and many other new technologies.

K. Heart rate variability: an index of brain processing in vegetative state? An artificial intelligence, data mining study[11]

According to F. Riganello, A. Candelieri, M. Quintieri, D. Conforti and G. Dolce have used data mining techniques to identify significant changes in heart rate variability in response to complex auditory stimuli with emotional value(music). They have documented the brain processing at varying levels of functional complexity in a coma like state with open eyes and situation of wakefulness (vegetative state). The parametric and non-parametric frequency spectra were computed on the heart rate, spectra were compared within/across subjects and music authors, and the spectra descriptors were entered into a 1-R rules data mining procedure (WEKA software Leave One Out and Ten Fold Cross validation)[11]. Heart rate spectral patterns of both patients and controls were independently classified and the emotions of control subjects were recorded as ‘positive’ or ‘negative’. WEKA tool was used to do one fold testing and the results were calculated 75-93.7% accuracy. Although preliminary, these findings suggest that autonomic changes with possible emotional value can be induced by complex stimuli also in vegetative state, with implications on the residual responsiveness of these subjects[11]. Also We see that heart rate variability descriptors and use of data mining methods can together yield useful results.

L. Mining physiological conditions from heart rate variability analysis[12]. C. Lin, J. Wang and P. Chung have used the features derived after long term monitoring of HRV indices. In this paper, proposed two methods for mining physiological conditions for parameters obtained HRV indices are the decision-tree learning method and hybrid learning method which integrates feature selection, feature extraction, and classifier construction processes. They examined the results and yielded classification accuracy 90.0%.

M. Clinical validation of software for a versatile variability analyser: Assessment of autonomic function[13]

AnanthakrishnanTS, Jindal GD, Sinha V, Jain RK, Kataria SK, Deshpande A Kand other scientists at Bhabha Atomic Research Centre have developed a medical instrument termed as medical analyser which is of great importance in measuring the several physiological variability’s simultaneously . This instrument collects data from various patients with established diagnoses. In this paper, they have discussed the software and packages and consistency of results achieved. The results have been consistent with the expected manifestations. We get to know the automation done in improving the techniques in physiological variability.

N. Heart rate variability: A review [14]

Written by Acharya UR, Paul Joseph K, Kannathal N, Lim CM, Suri JS, It is realized by their review paper that while analysing the parameter of physiological variability, considering Heart Rate Variability (HRV) is vital as it provides a powerful means of observing the interplay between sympathetic and para-sympathetic nervous systems. It helps us to know various physiological factors modulating the normal rhythm of heart. Heart rate (HR) is a variable signal and its variation may contain indicators of current disease or warnings about impending cardiac disease. In this paper various applications of HRV and other analysing techniques for analysing HRV are studied.

L. Emotion recognition system using short-term monitoring of physiological signals[15]

K. Kim, S. Bang and S. Kim have developed physiological signal based emotion recognition system based on records of physiological signals such as electrocardiogram, skin temperature variation and electro-dermal activity. The signals reflected effect of emotions on ANS. After extracting features, a classification problem was formed. It had input as large overlap of clusters and large variance within clusters. A support vector machine resolved this difficulty with correct results upto 78.4% and 61.8% for 3-4 categories.

III. CONCLUSION

In this paper,we have seen recent research work done in order to improve the medical facilities by automating the task of disease diagnoses and patient monitoring. Various pre designed data mining algorithms can be used for mining the data collected on physiological variability. The use of non-invasive methods for obtaining raw physiological parameters has eased the data collection task. It is concludedthat more accurate results can be derived by developing new data mining algorithms or comparative performance analysis on different physiological data.

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