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Implications of Big Data for Healthcare in Body Sensor Networks

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Abstract: *Big data analytics enhance modern healthcare by providing personalized medicine based on predictive prescriptions. A model of three layered data sharing for Big Heart Data is developed which uncovers the scope of cardiac remodelling. Remodelling helps in predicting status of heart health informatics based on existing database and prioritizing patient's recent-past cardiac activities. The concept was found to indicate early stages of heart failure leaving ample time to protect the patient from an acute cardiac arrest. A comparative analysis of Activation States and Rest-Task Pair Connectivity of brain is also conducted. Experimental explanations are also provided by recognition process and it opened the scope of not only detecting but also curing dementia by Body Sensor Networking (BSN). BSN can also aid rural cardiac treatments. Big Health Data leads to explore a new era of remotely testing, diagnosing and even curing particular diseases at an early stage without complex medications.*

Index Terms: *Big Heart Data, Big Brain Data, Cardiac Remodelling, Functional Connectivity, Body Sensor Networks.*

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I. Introduction

In the last century, engineering advances modified the notion of healthcare. Automation is encroaching in every possible domain of medical sciences from simplifying a complex surgery by incorporating surgical robots[1] to designing e-healthcare system for rural areas or smart hospitals for earlier implications in developing townships[2]. The development of wireless and mobile computing is changing our perception of healthcare, its easily imaginable nowadays to provide necessary healthcare to anyone at any time[3], no matter in which part of the world they are located in. Current Hospital Information System (HIS) are mostly manually controlled (as end user, where one human being works on a few computers to control) and suffer certain disadvantages like fixed information point or inflexible networking which can be waived off on using any platforms based on Internet of Things (IOT).

Big data and IOT work in conjunction. The amount of healthcare data is enormous and is further increasing with leaps and bounds on including concepts like e-healthcare or m-Health over last few decades.[4] The data includes all sorts of patient data, working-units' data (comprises of mainly doctors, nurses, interns etc.), pathological and surgical data and different types of complex mixed data. Minor inaccuracies expand exponentially with volume of growth of big data and so there is a conception of calling the same as 'dirty data'.[5] There are two basic applications of big health data that promises a new paradigm of patient-care. Those are generation of new knowledge about the effectiveness of treatments and the prediction of outcomes; which can be achieved by logical processing of current and recent past healthcare data by means of any doubly stochastic process like Hidden Markov Models (HMMs).

Using the body as the medium and skeleton as the waveguide the basic concept of Body Sensor Networks (BSN) developed a few years back[6] with the notion of accumulating several bioinspired principles under a singular platform that can be beneficial for developing BSN and its early hardware, software and networking equivalents. But the scope of implication is solely responsible on intelligent clustering of 'like-events' of a human body and its state prediction with respect to the other (may it be completely biological or a domain of bio-sensors); which cannot be possible without intelligent information handling and offering shortest communication path from one interactive node to another in an automated environment.

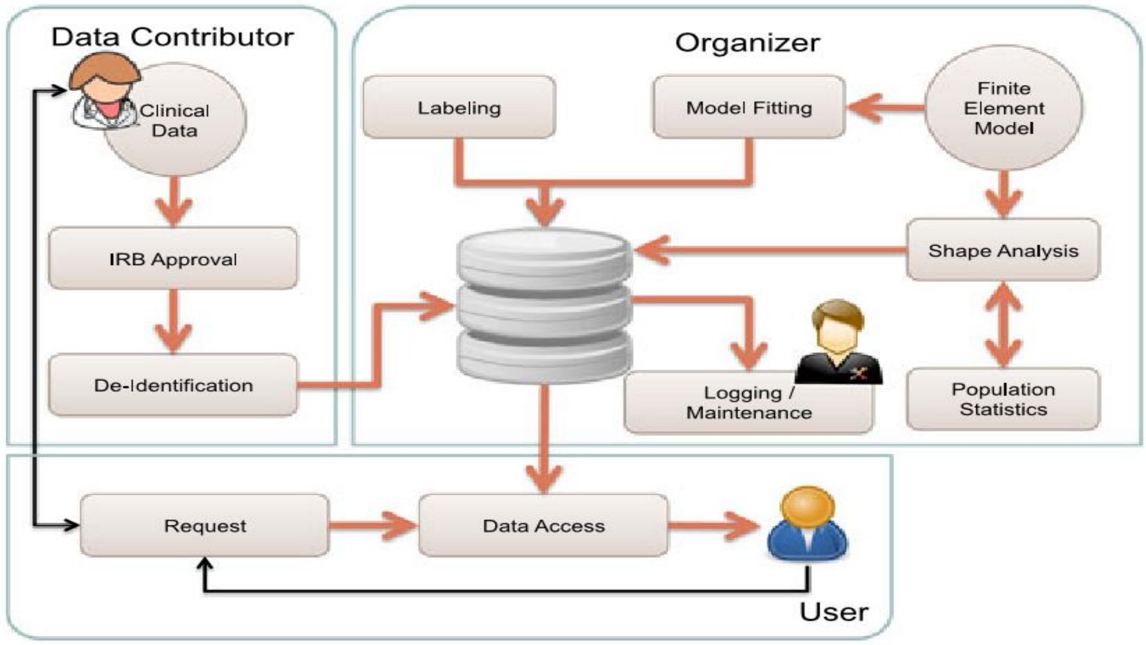
Big data analytics enhanced modern healthcare by providing personalized medicine and prescriptive analytics on logically synchronizing clinical risk intervention and related predictive modules. The paper discusses cardiac data handling and an efficient concept of cardiac remodelling to predict early indications of heart failures. Next, functional interactions for big brain data in terms of Activity analysis and a new concept of Task-Rest pair connectivity is proposed. Finally, the scopes of involving different schemes of Big Health Data for BSN realization is observed. A developed notion of identifyingdementia and curing the disease by BSN equivalent rather than complex medications is also described in this section.

II. Big Heart Data

The burden of heart disease is rapidly worsening due to the increasing prevalence of obesity and diabetes. Data sharing and open database resources for heart health informatics are important for advancing our understanding of cardiovascular function, disease progression and therapeutics. In the last decade, cardiovascular disease (CVD) was detected as the world's leading cause of morbidity and mortality[7].Reports claim obesity has overtaken tobacco as a cause of mortality and globally is the most triggering attribute for CVDs[8].

2.1.Data Sharing Module

Figure 1: Model of three layered medical data sharing

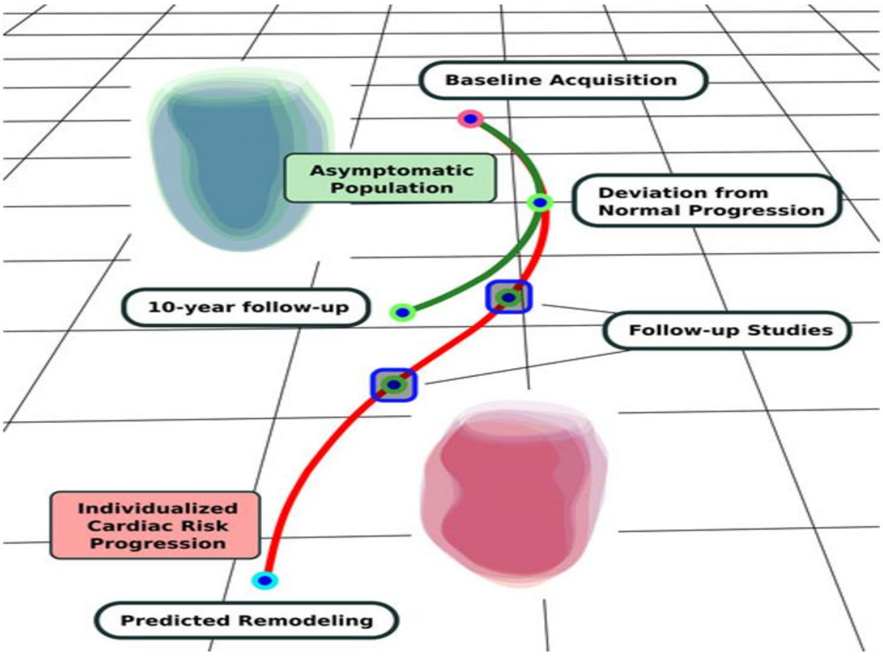


The domain of cardiac researches observed efforts to establish infrastructures for data sharing by providing anonymized baseline examinations, imaging data and other derived computations such as anatomical models and statistical shape analysis.Extreme granularity of heart data creates an open challenge to researchers for uniform CVD data handling. Informally, three basic pillars for data sharing are considered: data contributors, organizers and users. As in Figure1, the data contributor is given the objective of basically a provider who is optimized for data release to a larger community for a greater good without jeopardizing patient's rules and related clinical interests. Data contributors have to take care of obtained informed consents compatible with data sharing, in conjunction with institutional review board (IRB) approvals. Access is released only to anonymized data. Anonymization brings in a process called deidentification which takes care of removing any health information that may release individual's identity. For example, there shouldn't be any name or date (except for year; as that is a much-generalized approach). These can be stored in metadata form, preferably concealed as a coded file name for enhanced security. Contributors also have the sole responsibility of approval of data usage.

The organizers hold some supportive positions for re checking contributors task before handing over access to users and also holds responsibility to maintain a seamless hand-over. The challenges for an organizer is to set up the skeletal infrastructure to an implementable structure for data sharing, to establish a smooth integration, storage and management of mixed complex data which may include, laboratory tests, pathological images or bio models. An optional task may also be assigned to an organizer to enhance data enrichment activities, which primarily include ontological annotations, labelling and model fitting or population analysis. Users must have certain responsibilities and are liable to maintain privacy. A defined terms and conditions in terms of a Data Distribution Agreement (DDA) can be generated which takes care upon the particulars of the research, the user is going to conduct. DDA also has the sole objective of controlling the research: permitting activities associated with medical improvements but opposing possible threats for mass destructions; particularly close inspections are carried on for the researches related to open surgeries, drugs or automated life supports.

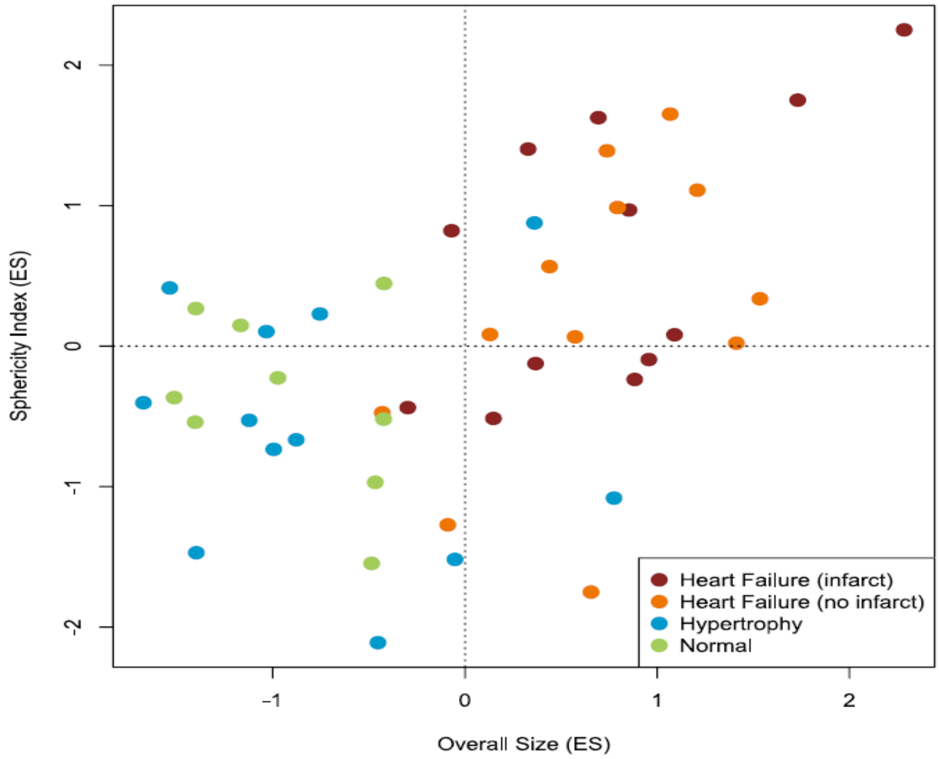
2.2. Cardiac Remodelling Module

Figure 2: Cardiac Remodelling over time (*green heart = adaptive remodelling due to growth, red heart = maladaptive remodelling*)



The human heart is changing shape (called remodelling) continuously for several factors like aging, genetic distributions and sharp changes in environmental attributes. The process can return false positives if linked to heart failure progressions[9] but is found to be working perfectly during normal growth, even in strenuous tasks like intensive physical exercises a sportsman goes through. Most effective application from remodelling is perhaps the adaptivity observed to detect early stages of heart failures. The reason for observing adaptive remodelling is because heart is gifted biologically the magical power to maintain its function in spite of pressure or volume overloading in acute phases. Figure 2 illustrates population based cardiac remodelling over time combining the shapes and possible clinical functions of the heart that can characterize the remodelling procedures. Individual dots in Figure2. illustrates the image acquisitions. Availability of Big Heart Data may enable predictions of remodelling and risk stratifications. As the heart remodels over time, its shape, volume, geometry, composition and mass changes. The width to height ratio of human heart (medically termed as ventricular sphericity) changes and for symptomatic cardiac arrests[10] often heart is found to become more spherical and less elliptical as it approaches the failure.Informally speaking, Ventricular sphericity suggests decreased survival. In contrast, asymptomatic individuals are found to undergo increased left ventricular (LV) chamber dimension[11], minimal changes in systolic rhythms and hypertrophy (involves overall dimension enlargement for over-functioning due to increased pressure before cardiac arrests).

Figure 3: Multivariate map constructed from the first two Principal Components Analysis of left-ventricular shape at end-systole



The importance and understanding of Cardiac remodelling is reflected in Figure 3. It shows the process followed for the rate of increase of LV size and ventricular sphericity from normal subjects with properly functional hearts to patients with tendencies of heart failure as a subset of cases reported from CAP database. Analysis of Figure3. is performed from the publicly available database adapted from University of Stony Brook, New York, USA. It revealed that Heart failure cases with and without infarct show elevated size and sphericity with these measures. However, hypertrophic cases are similar in these measures to normal volunteers. Lastly, statistical cardiac study over last two decades has proved our proposition to be correct by indicating a relationship between risk quantization (for triggering factors like hypertension, smoking, sex and diabetes) with LV modelling. The cardiac remodelling is found to be the most effective application of big heart data for patient safety and predicting heart failure with sufficient time to start medications and prevent lives.

III. Big Brain Data: Functional Interactions

Non-invasive studies of human brain are uncovering mysteries of human mind over last few decades. Considering that neural representations are heterogeneously distributed, they vary by cognitive state and the processes involve self-routed communication between different lobes of the brainand the space of interactions is massive[12], a significant way of handling the neurological database deserves special attention. Development of functional Magnetic Resonance Imaging (fMRI) developed the scope of exploiting susceptibility in Blood Oxygenation Level Dependent (BOLD)[13] and detecting neuronal activity in a generalized paradigm.

With advent of functional connectivity, the common practice of using activation as basic unit of study was replaced by prioritized pairwise relationships. Most functional connectivity studies are conducted at rest though the resting state is typically a subset of a complete cognition procedure. Generally speaking, functional connectivity can be best described by combined effect of rest states and task states, though non-sleep stages of rest states are mostly composed of recurrence or trailing end of cognition of recent past task states. The logic of BOLD relies upon two types of task states: externally evoked by some stimuli (for example, any standard audio-visual inputs) and involuntary activities triggered to maintain current cognitive states (regular activities of everyday life). Interestingly, a resting state can be considered as a connector between two active task states. On dealing with the artifacts, predefined models for evoked activities leave endogenous residuals, which opens up the chances of correlating the latter with voxels for maintaining logical connectivity in different cognitive states across all primary lobes.

For the current study, selective attention was considered for a simpler realization. Imagine a man knows only four people – one a friend (positive evoke) and another a foe (negative evoke). The third guy appeared to be his friend for a long period of time but later turned to a foe (false positive evoke) and the fourth was an utter disgust for our subject under study, though he expresses friendliness to him (false negative evoke). Now an image of each is produced to the man and neuronal activities are noticed. Three possible stages of image display and all possible transitions among the three are taken under consideration: bright image, blurred image and darkened image (hard to notice). For example, when a bright image is produced, the face-selection activity cortex gets triggered for identification in brain, but for a darkened image the man has to hunt through the white dots in the black page to make an idea whose picture is darkened here. So, in the second case, scene-selection visual cortex gets triggered. As an outcome, attended information gets prioritized as they strengthened representations; computational accuracy is also found to be far better than unattended information.

Models of cognitive control suggest another possible mechanism of attention prioritization to handle the bulk of big data processed in our brain. The model emphasizes guidance of activities among neural pathways which link attention to long-rang synchrony[14]. Attention is here considered like switching train tracks, face selection activity cortex (frontal) or scene selection visual cortex (parietal)establishes connections between visual areas to route sensory information along shortest possible pathway. The method adapted by our brain for identifying the shortest path to connect with is still unknown but it is clear from past researches over two decades that there is not one definite algorithm followed, there are a few hundreds of them which are yet to be discovered[12]. Occipital cortex does the selection of algorithm to choose the path but the basis of selection is suspected to be dependent on the amount of sensory information.

Task based connectivity finds significance in a real-world complex situation like: Mr. X is travelling to City Y which has ten possible choices of hotels of similar prices and same facilities. Now what drives Mr. X to pick up the first hotel from all the ten units? The truth lies deep beneath the brain that involves interaction between striatum and hippocampus. In a period of 1 microsecond for ten similar choices 10 billion bytes of data are produced in parietal region to decide upon. When a stimulus is triggered of all the 10 billion bytes, the parent value created in striatum plug in the stimulus. Next, via functional connectivity, reactivated stimuli are generated from other possible evoked incidences – preferences are done by logical association to the primary stimuli, by the brain itself. The technique opens up a new research era to study the method of data storage in brain and trying to mimic it viaelectronic circuitry.

Figure 4 describes full connectivity by splitting them into resting and task connectivity and finally recorrelating back in 4.E. The differences between univariate and multivariate activations are also observed in Figure 4.A and Figure 4.B. Result Section of Figure 4 compares the outputs by both activity and correlation-based analysis leaving the scopes to the reader to choose the better and more efficient one. The univariate activation discussed in Figure 4.A relates average amplitude of BOLD activity evoked by events whereas for

Figure 4: Analysis of Functional Interactions in Brain from fMRI data for Activations and Rest-Task Pair Connectivity

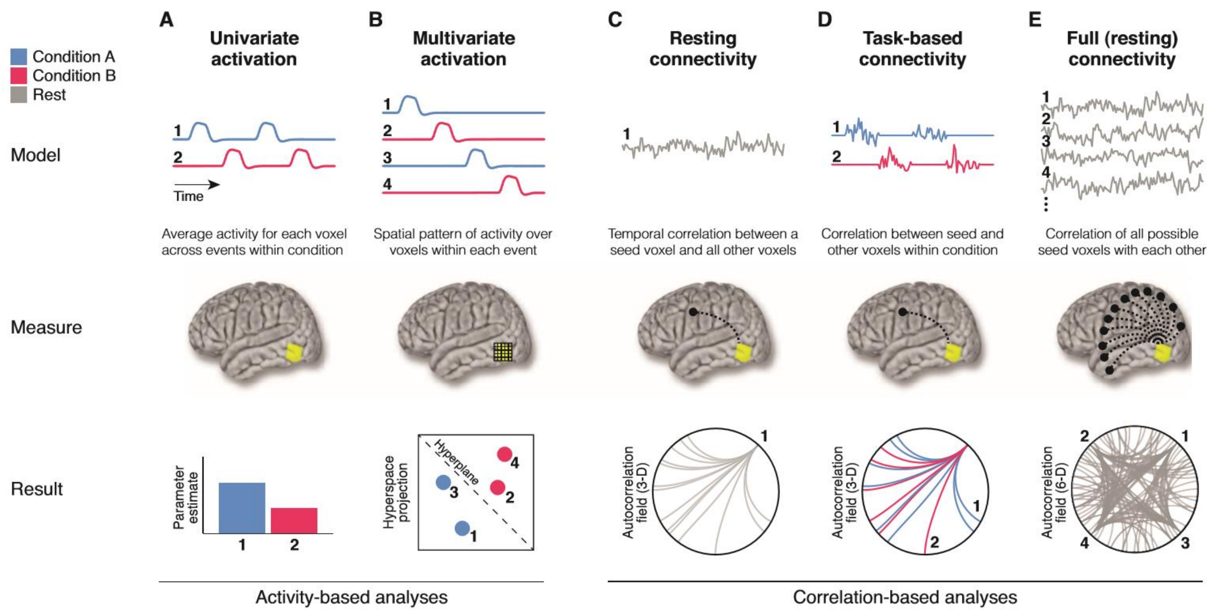


Figure 4.B multivariate neuro-fuzzy classifiers are trained on predesignated patterns of activations to decode heterogenous representations for specific patterns; procedure relates for brains in infancy, for example, when a baby learns to speak basics of his/her mother tongue. Figure 4.C considers primarily temporal correlations for resting connectivity of multiple nascent regions with remainders or trailing-end thoughts for past or possible upcoming task regions. Figure 4.D highlights the methods adapted for examining differences among cognitive state via task-based connectivity mainly in frontal and parietal vortex. Figure 4.E is the result of correlating Figure 4.C and 4.D and the full connectivity considers all pairwise correlations across the brain.

IV. Big Health Data for Body Sensor Networks

Body Sensor Networks (BSN), sometimes also referred as Body Area Networks (BAN) emerged as an active field of research to connect and operate a heterogenous variety of sensors, within, on or in close proximity of human body[15] in order to develop a systematic regularized scheme of health monitoring with minimal units of testing for the grand dream scopes of designing a fully automated hospital. Shortcomings of traditional wearables with complex circuitries which may lead to mass panic, lacking comfortability and insufficient accuracies need to be replaced upon [16]. To survive, any animal including human beings relies totally upon their sensory systems and so bio sensing needs to play a spinal role on developing Body Sensor Networks (BSN). Multiple innovations in domains of somatosensory, visual, gustatory, olfactory and auditory sensing are in progress at Hamlyn Center, Imperial College London. For example, artificial hair cells are developed to mimic cellular fabrication in scalp, or a silicon retina is generated few months back to give vision to a blind or an e-AR sensor is under development to meet the objectives of semi-circular canals (identifying rotational motions) and otoliths (identifying translational motions), the two sensory mechanisms in vestibule of human ear[17].

BSN nodes encapsulates energy source of human body creating an interface between physiological units, sensors, a multivariate signal processor and communication transceiver. Units like insulin pumps or robotic prosthetic offers data storage or feedback control. Informally speaking, an ideal BSN needs a few hundreds of homogenous sensors, in terms of functionality with unique placement features. Three distinct types of sensors are of primary concern – *I) Physiological Sensors*, *II) Biokinetic Sensors* and *III) Ambient Sensors*. Physiological sensors are expected to keep controls on anything related to blood pressure, temperature and oxygen; core body temperature; glucose monitoring along with non-invasive units like respiratory inductive plethysmography, electrocardiography (ECG), electromyography (EMG) or EEG. Biokinetic sensors are optimized to study motions in terms of momentum, angular and linear acceleration and rotation. All environmental, geographic and edaphic factors are controlled by Ambient sensors, such as photonic incidences, humidity, sound pressure level, external temperature, shift in geographic domains and effects of any turbulent irregular factors like cyclones, earthquakes, tsunami or floods.

Intelligent handling of cardiac remodelling opens the scope of preventing all sorts of cardiac diseases along with predicting chances of cardiac arrests. Given the circumstances, a generic sensor can measure arterial flows from particular sites of concern and return the decision logic to an eHealth center for doctors to analyze and suggest possible activities to generate execution orders to the end-user i.e. the sensor carrier. BSN realization in terms of brain can be performed by using any existing wireless Electroencephalogram (EEG) module to update necessities. EEG modules are painless wearables (structure similar to helmets or hair bands). It can be triggered for multiple controls on the body networking, from promising a good sleep to gaining control over emotions for a greater good. fMRI data though produces higher accuracy more flexibility is offered by EEG modules, so the latter is often preferred among researches; though both can add to promise a smarter brain analysis for implications in BSN.

Hyperspace projections for activity-based analysis promises a sharper decision boundary for monitoring a person in a generalized broader approach. For example, an asylum may use the concept to regularize daily habits of admitted patients. However, rest-task pairing gives a deeper scope for control. Imagine a situation when an engineer is failing to optimize a problem again and again over a couple of days. Such a situation generally occurs when a dead-loop occurs in the brain between striatum and hippocampus and 'alternate throwing and catching' of the same stimuli of a few billion options occur iteratively. Harder the person tries to figure out a newer approach, greater is the power of neuronal pressure released for incidence on sensing cortex of hippocampus which confirms a stronger reflection back to striatum. Repeated dead looping for a couple of months can grow nascent symptoms of dementia as well[18], which can be detected by our module far before showing symptoms. Interestingly, 'throwing and catching' terminates at rest-state and though our central nervous system fails generally to find out the shortest path of solution by communicating in frontal and parietal vortex, by some complex recurrent C-type path detection it achieves the task at least partially (if not fully) in a period of seven to eight hours sleep. Waking up results in the recalling of iterative loop once again if the patient is approaching dementia. BSN logic can update the traces of information from various cerebral hemispheres at rest stage and decode down to the solution of the optimization problem for user's access once he wakes up.

Once, the patient can reach out of dead looping forcefully, the chances of dementia falls down by approximately 80% for next few years. Basically, implications of Big health data via BSN networking can promise tomorrow's Earth a better healthy life not only by early detection of diseases but also curing it to certain extent without regular medications.

V. Conclusion

Population based tools proved to be most efficient in big heart data when individual cardiac risk prediction is mapped. A three-layered data sharing unit for Big Heart Data is developed which promises eHealth service by cardiologist's assistance in terms of medication or diagnostics in rural areas. The contrast between symptomatic and asymptomatic patients are drawn for ventricular sphericity and experimental results by logical cardiac remodelling proved to indicate fatal heart quality deterioration towards cardiac failure much before the heart arrest, leaving a chance of early medication and saving lives. Functional interactions have taken over activity analysis for several advantages like rest-task paired relationships. A comparative study among the two proved the higher efficiency of the latter in accurately handling Big brain database at a rate of 10 billion bytes of neuronal data per microsecond. The triggering features of task-based connectivity for visual cortex (parietal lobe) and activity cortex (frontal lobe) between striatum and hippocampus is studied and a condition of death-looping for repetitive similar thinking is investigated. Big data dependent analytics opened the scopes of detecting dementia at an early stage by means of Body Sensor Networking and also generated scopes of curing the same; simply by logical data processing instead of long term complex medications.

5.1. Scopes for Future Extensions

Researches can be extended for generating dynamic syndromes in order to work in a mixed domain of correlation between activity analysis and functional interactions to provide a generalized notion of brain activities. When it will be possible for designing a complete map of brain, the entire neuronal flow and the triggering causes will be studied which has a high possibility to uncover scopes of preventing tumorous growth. A complete cardiovascular imaging with effective handling of the massive data related to the arterial flows of central nervous systems can provide solutions to basic problems like preventing lipid depositions in arteries. Involving scopes of BSN with enhanced imaging and data analytics from Big Health can lead to the possibilities of designing a completely automated healthcare system in coming decades.

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