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A Survey of Challenges and Applications of Wireless Body Area Network (WBAN) and Role of A Virtual Doctor Server in Existing Architecture

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***Abstract* – Wireless body area network has gained much interest and became emerging technology at health service facilities due to its wide range of utility and vital role to improve the human health. In this research paper, we are conducting a comprehensive survey of wireless Body Area Network (WBAN) and also introducing a virtual doctor server (VDS) in existing WBAN architecture. Existing architecture of WBAN consists of: wireless sensor, wireless actuator node , wireless central unit and wireless Personal Device (PD). Personal Digital Assistant (PDA) or smart phone can be used as PD. Based on the existing architecture mentioned above, we propose a design concept for a virtual doctor server (VDS) to support various patient health care services. VDS will keep the historical data about the patient, generate the daily tips and advices for him, call the doctor or emergency squad if required and can provide first aid assistance instructions on patient or any of his close relative's PDA's.**

Keywords:- Wireless Body Area Network, Client Server architecture for E-health , E-health technologies survey, Innovation in health care.

I. INTRODUCTION

A wireless body area network (WBAN) is a radio frequency (RF) based wireless networking technology that interconnects tiny nodes with sensor or actuator capabilities in, on, or around a human body. As describe in [1], the transmissions of these nodes cover a short range of about 2 m, and other specifications of WBAN are shown in
Table **1**.

Table 1: WBAN Specifications

Attribute	Value
Distance	2 meter stander 5 meter special case
Start up time	< 100 ns
Network Setup time	<1 sec / device
Power consumption	~ 1mW/Mbps
Network density	2-4 Nets / m^2
Latency (end to end)	10 ms
Network size	Max 100 devices /Network

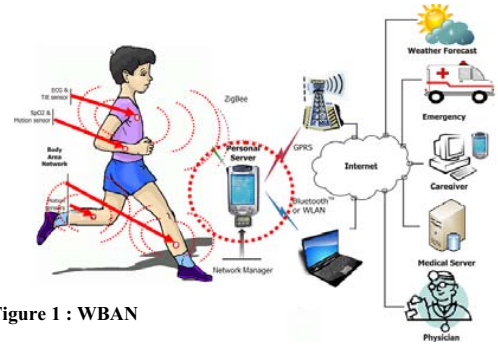

Figure 1 : WBAN

As shown in figure 1 Wireless Body Area Network is a special kind of network, which is designed and develops for Human body, to monitor, manage and communicate different vital signs of the human body like temperature, Blood pressure and ECG etc. These vital signs can be monitored by using different sensor installed on clothes or on the body or even under the human skin. Any kind of drug can be injected using actuator installed on the human body like, to control the blood pressure, temperature or can inject any life-saving drugs. Central unit is responsible to establish communication between sensors, actuators and cellular phone in wireless fashion. Cellular phone of that person can be used to transmit all information to and from the human body to the external world (physician, emergency). This kind of wireless personal network around and near the human body is called Wireless Body Area Network (WBAN) where each body is assigned an IP address. IEEE 802.15 Task Group 6 standard is assigned to develop energy-efficient devices and to develop applications for WBAN.

In what follows we present a survey of major existing WBAN applications, technologies, architectures, protocols, available infrastructure and available standards.

II. BACKGROUND

In this section we will provide a survey of all the applications and areas of life where WBAN is providing its vital role and giving quality to human life. We will also conduct a server of different devices already available to build WBAN.

A. Applications of wban

Application of WBAN can categorized depending on the domain of application. In what follow we present major WBAN domains of application.

1) WBAN Application for medical treatment and diagnosis

There are myriad of possibilities where WBANs are useful for diagnosis or treatment of diseases. Many researchers have conducted research in this regards [2],[3],[4],[5][6][22] as summarized in table 2.

Table 2: Role of WBAN in Health care

Field of application/Disease	Sensors,	Role of WBAN
Cardiovascular Disease (CVD) 30% of all global deaths 17.5 million Deaths per year, 2015, expected 20	Pulse oxi-meter Heart rate sensor ECG sensor	The corresponding medical staff can do treatment preparation in advance as they receive vital information regarding heart rate and irregularities of the heart

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million patients. [7]		while monitoring the health status of the patient. [8],[9],[10]
Paraplegic 2 million people worldwide, live with a spinal cord injury (SCI). Each year 11,000 new injuries are reported. Every 49 minutes a new injury occurs[11]	Accelerometer, Gyroscope 1. Sensors for Legs position 2. Sensors attached with nerves 3. Actuators positioned on the legs can stimulate the muscles	Interaction between the data from the sensors and the actuators makes it possible to restore the ability to move.[12]
Broken teeth & building crowns and bridges	Radio Frequency devices RFID	to reduce errors and improve productivity in the development of dental prosthetics
Cancer 12.7 million cancer cases and 7.6 million cancer deaths are estimated to have occurred in 2008. [6]	Nitric oxide Sensor	Sensor can be placed in the suspect locations and doctor can start treatment as soon as a cancer cell detected.
Alzheimer, depression, Hypertension More then 65 year old citizen. 357 million in 1990 Expected 761 million in 2025		Wireless sensor network can help homebound and elderly people who often feel lonely and depressed by detecting any abnormal situation and alerting neighbors, family or the nearest hospital.
Diabetes Worldwide, more than 246 million people, expected to rise to 380 million by 2025. [13]	A biosensor gyroscope Insulin Actuator	If the sensor monitors a sudden drop of glucose, a signal can be sent to the actuator in order to start the injection of insulin. Consequently, the patient will experience fewer nuisances from his disease. [14]
Asthma 300 million people worldwide, 250,000 annual deaths [15]	Allergic sensor	Sensor nodes that can sense the allergic agents in the air and report the status continuously to the physician and/or to the patient himself.[2]
Defective Tooth positions treatments [22]	A set of dental retainers equipped with the RFID temperature sensor/data logger module	for observing the patient's dental retainer usage.
Epileptic Seizures Strike Early Warning 275,000 deaths from stroke each year. [16]	Mobi	The portable unit "Mobi" is designed to detect abnormal brain activity that happens before a seizure. When the signs of electrical trouble are picked up the device will transmit a warning to a receiver and the patient could then take steps to set down or tell someone.
Pain treatment	Actuator with pain killer	Actuator is a spinal cord Stimulator implanted in the body for long-term pain relief.
Visually impaired 285 million people are visually impaired worldwide: 39 million are blind and 246 have low vision. [17]	artificial retina matrix of micro sensors external camera	An artificial retina, consisting of a matrix of micro sensors, can be implanted into the eye beneath the surface of the retina. The artificial retina translates the electrical impulses into neurological signals. The input can be obtained locally from light sensitive sensors or by an external camera mounted on a pair of glasses
High Blood pressure High blood pressure contributes to more than 12.7 million strokes worldwide. [16]	Blood pressure sensor Actuator with medicine	If the sensor monitors a change in blood pressure more then threshold value, a signal can be sent to the actuator in order to start the injection medicine. Consequently, there are lesser chance of strokes
Parkinson's disease An estimated seven to 10 million people worldwide are living with Parkinson's disease. [18], [19]	motion sensors Accelerometer	estimate the severity of tremor, bradykinesia, and dyskinesia from accelerometer data and performed a thorough assessment .[4]
Renal failure 2008, 2 million people with end-stage kidney disease due to diabetes in United States. [13]		Can provide portable, non-invasive fall risk assessment in end stage renal disease patients on hemodialysis
Post operative monitoring	Temperature sensor, blood pressure sensor, Heart rate sensor, ECG	the patient will no longer need to stay in bed, but will be able to move around freely

2) WBAN Application for Training schedules of professional athletes:

WBAN further enables to tune more effectively the training schedules of professional athletes.

3) WBAN Application if Public safety and preventing medical accidents

Approximately 98'000 people die every year due to medical accidents caused by human error. Sensor Network can maintain a log of previous medical accidents, and can notify the occurrence of the same accident and thus can reduce many medical accidents.

4) WBAN application for Safeguarding of uniformed personnel

WBAN can be used by firefighters, policemen or in a military environment. The WBAN monitors the level of toxics in the air and warns the firefighters or soldiers if a life-threatening level is detected.

5) Application of WBAN in Consumer Electronics

Next to purely medical applications, a WBAN can include appliances such as an MP3-player, head-mounted (computer) displays, Microphone, Camera, Advanced human-computer interfaces such as a neural interface, Gaming purposes, and Virtual reality.

B. Types and use of different devices

1) Wireless Sensor node:

A device that responds to and gathers data on physical stimuli processes the data if necessary and reports this information wirelessly. It consists of several components: sensor hardware, a power unit, a processor, memory and a transmitter or transceiver. According to the study [5], one of the selective sensors used for Health care applications are discussed bellow in table 3:

Table 3: WBAN Sensor

Application	Data Rate	Bandwidth	Accuracy
ECG (12 leads)	288 kbps	100-1000 Hz	12 bits
ECG (6 leads)	71 kbps	100-500 Hz	12 bits
EMG	320 kbps	0-10,000 Hz	16 bits
EEG (12 leads)	43.2 kbps	0-150 Hz	12 bits
Blood saturation	16 bps	0-1 Hz	8 bits
Glucose monitoring	1600 bps	0-50 Hz	16 bits
Temperature	120 bps	0-1 Hz	8 bits
Motion sensor	35 kbps	0-500 Hz	12 bits
Cochlear implant	100 kbps		
Artificial retina	50-700 kbps		
Audio	1 Mbps		
Voice	50-10 Mbps		

2) Wireless Actuator node:

Next to sensing devices, the patient has actuators, which act as drug-delivery systems. The medicine can be delivered on predetermined moments, triggered by an external source (i.e. a doctor who analyzes the data) or immediately when sensors notice a problem. An actuator node can consist of a receiver or transceiver, a power unit, memory and main component is actuator hardware (reservoir to hold the medicine and hardware to manage the medicine).

3) Wireless Personal Device (PD):

This device is also called a Body Control Unit (BCU), body gateway or a sink. PD can be a dedicated unit or in some implementations, a Personal Digital Assistant (PDA) or smart phone is used. The Main purpose of this unit is to collect all the information attained by the sensors and actuators and communicate it to the user (patient, nurse, etc.) via an external gateway. The main components of this device are a power unit, a large processor, a large memory and a transceiver.

III. PROPOSED VIRTUAL DOCATOR BASED WBAN ARCHITECTURE

In figure 3 we are introducing the concept of virtual doctor server (VDS) that is based on WBAN architecture shown in figure 2: The VDS integrated various applications of WBAN to manage the health service provided to the patient and provides assistance to health care service providers in emergency situation..

Figure 2: Existing WBAN Architecture

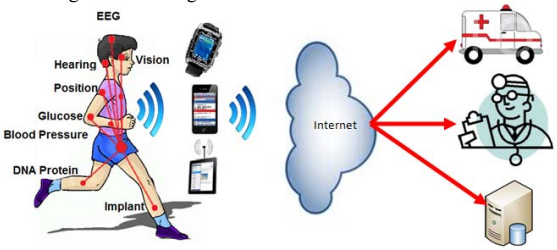
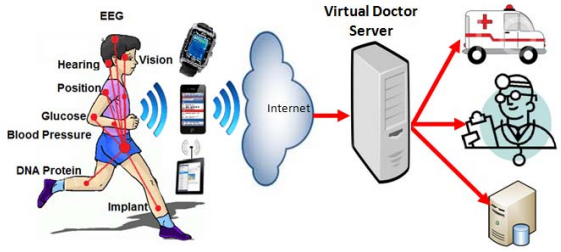


Figure 3: Proposed VDS architecture



In particular, VDS may have following responsibilities:

- Keep the history of patient
- keep track of medicines taken by patient and Remind him to take the medicines on time by PD unit
- Gives advices to the patient/patient helper, on the bases of best practices and vital signs taken by sensors
- Call paramedic /emergency squad or ambulance if necessary
- Maintain QOS, security, confidentiality and privacy

Patient can give his input like his condition and feelings by using PD unit and vital signs will be taken by sensor, **VDS** will give advices based on patient history + database + best practices + vital signs. Advices are like:

- Its normal don't worry
- Patient should take some action like take rest ect.
- Patient should take first aid action liken take emergency medicine; lay down straight and no movement till doctor/paramedic will arrive ect.
- If patient will become unconscious then VSD will advice the helper for first aid steps like hart pumping, given artificial breathing, give emergency pills ect.

IV. THE MAIN CHALLENGES IN WBAN:

WBAN is an emerging technology, lots of issues still needs to address, and still many problems require better solution. WBAN is facing both ethical and technical challenges like privacy is most important and critical ethical issue yet to be addressed properly, and main technical issue is to provide better Human Computer Interaction (HCI). Other technical challengers are shown bellow table 3.

Table 4: Common Challenges in WSN and WBAN

Challenges	Wireless Sensor Network	Wireless Body Area Network
Scale	Monitored environment (meters / kilometers)	Human body (centimeters / meters)
Node Density	Many redundant nodes for wide area coverage	Fewer, limited in space
Result accuracy	Through node redundancy	Through node accuracy and robustness
Node Tasks	Node performs a dedicated task	Node performs multiple tasks
Node Size	Small is preferred, but not important	Small is essential low on complexity, light in weight, power efficient, easy to use and reconfigurable, storage devices need to facilitate remotely
Network Topology	Very likely to be fixed or static	More variable due to body movement
Data Rates	Event based monitoring Events can happen irregularly	Monitoring human physiological activities Vary in a more periodic manner
Latency		
Mobility	Nodes are usually considered to be stationary, and any node mobility does not occur in groups	Nodes affiliated with the same wearer move together and in the same direction
Node Replacement	Performed easily, nodes even disposable	Replacement of implanted nodes difficult
Node Lifetime	Several years / months	Several years / months, smaller battery capacity
Power Supply	Accessible and likely to be replaced more easily and frequently	Inaccessible and difficult to replaced in an implantable setting
Power Demand	Likely to be large, energy supply easier	Likely to be lower, energy supply more difficult
Energy Scavenging Source	Most likely solar and wind power	Most likely motion (vibration) and thermal (body heat)
Biocompatibility	Not a consideration in most applications	A must for implants and some external sensors
Security Level	Lower	Higher, to protect patient information
Impact of Data Loss	Likely to be compensated by redundant nodes	More significant, may require additional measures to ensure QoS and real-time data delivery.
Wireless Technology	Bluetooth, ZigBee, GPRS, WLAN	Low power technology required
Authenticity of nod installed on correct place	No need	Needs to install sensors on correct place and correct person
Real time communication	Not required in all the cases	Need grantee of accuracy and on time delivery of message
Architecture	Wires nodes communicate in wifi are ad-hoc mode fashion	Sensor, Actuator and central unit communicate through PDA

V. OPEN RESEARCH ISSUES

The discussions above clearly show that, although a lot of research is going on, still a lot of open issues exist.

A. Physical layer Issues

Several researchers have already started studying the propagation of electromagnetic waves in, and on the body and a few models for the physical layer are proposed. It should be noticed that none of them take the movements of the body into account, although movements can have a

severe impact on the received signal strength. Further, new emerging technologies such as galvanic coupling and transformation of information via the bones offer promising results and need to be investigated more thoroughly.

B. Data Link Layer issues

Although some protocols already exist that take care of the data link layer and networking, this area still has a lot of open research issues. On the data link layer, more WBAN specific MAC-protocols need to be developed that take into account the movement of the body, i.e. the mobility of the nodes, additional low-power features such as an adaptive duty cycle for lowering the idle listening and overhearing, the use of the human physiology such as heart beat to ensure time synchronization and so on.

C. Network layer

A promising research track is the combination of thermal routing with more energy-efficient mechanisms. More efficient QoS-mechanisms are needed, for example, based on the Body Qos framework. Other interesting open research issues are mobility support embedded in the protocol, security, inter operability and so on. In order to define a globally optimal system, it might be necessary to unite several of these mechanisms in a cross-layer protocol.

D. Physical characteristics of sensor/actuator materials and electronic circuits

As sensors/actuators are going to be put on human bodies or even implanted, their size, form factor, and physical compatibility to human tissues are crucial. This motivates the search for and synthesis of novel materials. At the same time, concerns regarding electronic and magnetic energy absorbed by human tissues from RF circuits placed in close proximity to humans mean that WBAN devices need to employ low transmission power and low transmission duty cycles. In this regard, Ultra-wideband (UWB) outperforms conventional transmission methods and thus attracts much attention.

E. Networking and resource management schemes

As the application scenarios of WBANs are different from traditional sensor networks, problems like power management, sensor calibration, and context-aware network configuration need to be revisited as well. Sensor node scans to join/leave the network at any time, and thus impose the requirements of configuring the devices on the fly. Dynamic management of resources, including both sensor functionalities and communication bandwidth, is also necessary.

F. Power supply issues

As all WBAN devices require an energy source for data collection, processing, and transmission, development of suitable power supplies becomes paramount. Most WBAN devices are powered by batteries, which may not even be replaceable in cases where the devices are implanted in the human body; thus, techniques like remote battery recharging are important. In addition to energy harvesting methods (e.g., based on body movements) many researchers are studying, recently researchers at MIT have reported wireless energy transmission to power electronic devices over a short range (i.e., several meters) using evanescent waves.

G. Energy issues

The use energy scavenging was not addressed in detail. With a smart combination of lower energy protocols and energy scavenging, the optimal solution for achieving autonomous Body Area Networks can be reached. For a WBAN, energy scavenging from on-body sources such as body heat and body vibration seems very well suited.

All the devices in wireless sensor networks are battery operated therefore, power challenge is present in almost every area of application of wireless sensor networks, but limitation of a smart sensor implanted on a person still poses even further challenge. In a full active mode a node can't operate more than a month because a typical alkaline battery provides about 50 watt-hours of energy. Any commercial applications have to guarantee that all the devices will work for at least a year without any maintenance / replacement. For example heart pacemaker's devices. The developers have to design better scheduling algorithms and power management schemes to deal with these power issues. Critical parameters in the design of a power efficient WBAN system are described as follows:

Average bandwidth	Influences the active communication time of wireless controllers and therefore the duty cycle of the system
Maximum required bandwidth	Critical for bursts of urgent messages, and affects the maximum latency for data transmissions
Active power	Determines the type, size and weight of the battery, as well as the battery life.
Standby power	Determines the maximum battery life, as a function of the system duty cycle
Startup time	Represents the overhead and determines the efficiency of individual transmissions
Communication setup	Protocol-related timing parameter that represents time necessary to (re)establish a connection between nodes or a node and a gateway
Standards based communication technology	Influences the system interoperability and application development time
Protocol stack size and processing requirements	Determine characteristics of the wireless sensor platform

H. Computation

Due to both limited power as well as memory, computation should also be limited. The biosensors cannot perform large bit computations due to lack of enough memory. Unlike conventional wireless sensor network nodes, biosensors do not have much that computational power. Since communication is vital and memory is low, little power remains for computation. A solution is that some sensors may have varying capabilities that communicate with each other and send out one collaborative data message.

I. Security, authentication, and privacy issues

The communication of health-related information between sensors in a WBAN and over the Internet to

servers is strictly private and confidential and should be encrypted to protect the patient's privacy. The medical staff collecting the data needs to be confident that the data is not tampered with and indeed originates from that patient. Further, it cannot be expected that an average person or the medical staff is capable of setting up and managing authentication and authorization processes. Moreover, the network should be accessible when the user is not capable of giving the password (e.g.to guarantee accessibility by paramedics in trauma situations). Security and privacy protection mechanisms use a significant part of the available energy and should therefore be energy-efficient and lightweight. The communication of health-related information between sensors in a WBAN is subject to the following security requirements**:**

Data confidentiality	It means that the transmitted information is strictly private and can only be accessed by authorized persons, e.g. the doctor attending the patient. It is usually achieved by encrypting the information before sending it using a secret key and can be both symmetrically and asymmetrically.
Data authenticity	It provides a means for making sure that the information is sent by the claimed sender. For this, a Message Authentication Code (MAC3) is calculated using a shared secret key.
Data integrity	It makes sure that the received information has not been tampered with. This can be inspected by verifying the MAC. Guarantee that the received data is recent and not a replayed old message to cause disruption. A famous t is to add a counter who is increased every time a message is sent.

J. Material Constraints

Another issue for wireless sensor network application to healthcare is material constraints. A biosensor should be implanted within the human body; therefore, the shape, size, and materials might be harmless to the body tissue. For example, a smart sensor designed to support the retina prosthesis might be small enough to fit within an eye. Furthermore, chemical reactions with body tissue and the disposal of the sensor are of extreme importance.

K. Robustness

Whenever the sensor devices are deployed in harsh or hostile environments, Robustness rates of device failure become high. Protocol designs must therefore have built-in mechanisms, that the failure of one node should not cause the entire network to cease operation.

L. Continuous operation

Continuous operation must be ensured along the life cycle of a biosensor, as it is expected to operate for days, sometimes weeks without operator intervention. Hence, it is important to keep the amount of communications to the minimum. It is necessary that those communications which occur for purposes other than the actual data communication should be minimized if it is impossible to eliminate them.

M. Rules of engagement

However, intelligent monitoring and treatment systems employing WBANs require standardized rules of engagement in ambulatory environments, providing point of care without limitation of the wearer's location/mobility while protecting the patient's privacy. Interoperability protocols at the application or domain level (e.g., sample rate, data precision, association/disassociation, device descriptions, and nomenclature) should all be addressed, and vendor-independent attributes and user interfaces shall be made available.

N. Quality of Service and Reliability

According to [1], [20], [21] proper quality of service (QoS) handling is an important part in the framework of risk management of medical applications. A crucial issue is the reliability of the transmission in order to guarantee that the monitored data is received correctly by the health care professionals. The reliability can be considered either end-to-end or on a per link base. Examples of reliability include the guaranteed delivery of data (i.e. packet delivery ratio), in-order-delivery. Moreover, messages should be delivered in reasonable time. The reliability of the network directly affects the quality of patient monitoring and in a worst-case scenario, it can be fatal when a life-threatening event has gone undetected. WBAN QoS for all network layers is as under:

Application layer:	(usually specified by users): It includes system lifetime, response time, data novelty, detection probability, data reliability and data resolution.
Transport layer:	It includes reliability, bandwidth, latency, and cost.
Network layer:	It includes path latency, routing maintenance, congestion probability, routing robustness and energy efficiency.
Connectivity Maintenance layer	it includes network diameter, network capacity, average path cost, connectivity, robustness and connectivity maintenance
Coverage Maintenance layer:	It includes coverage percentage, coverage reliability, coverage robustness, coverage maintenance.
MAC layer:	It includes communication range, throughput, transmission reliability, and energy efficiency
Physical layer:	It includes physical capabilities impose resource

O. Usability

In most cases, a WBAN will be set up in a hospital by medical staff, not by ICT-engineers. Consequently, the network should be capable of configuring and maintaining itself automatically, i.e. self-organization and self-maintenance should be supported. Whenever a node is put on the body and turned on, it should be able to join the network and set up routes without any external intervention. The self-organizing aspect also includes the problem of addressing the nodes. An address can be configured at manufacturing time (e.g. the MAC-address) or at setup time by the network itself. Further, the network should be quickly reconfigurable, for adding new services. When a route fails, a backup path should be set up. The devices may be scattered over and in the whole body. The exact location of a device will depend on the application, e.g. a heart sensor obviously must be placed in the neighborhood of the heart. A temperature sensor can be placed almost anywhere. There is no consensus of researchers over the ideal body location for some sensor

nodes, i.e. motion sensors, as the interpretation of the measured data is not always the same. The network should not be regarded as a static one. The body may be in motion (e.g. walking, running, twisting, etc.) which induces channel fading and shadowing effects. The nodes should have a small form factor consistent with wearable and implanted applications. This will make WBANs invisible and unobtrusive.

P. Signal & Path Performance

The structure of a human body (flash and bones) is a factor and plays a vital role in signal and path loss for Wireless body area network and this property of WBAN entirely different from convention WSN. Many researchers have been conducted to model signal loss throughout in a human body. Another interesting research area is to use human body as a medium to transmit the electrical signals and human body itself is used to transmit signal form one area of a body to another area.

VI. CONCLUSIONS

The aim of this survey paper was to investigate the role of WBAN in improving human Quality of life. In this survey, we tried to scan all possible application of WBAN in daily life, the challenges WBAN facing nowadays and open research issues. We have also explained existing architecture of WBAN and proposed a new component VSD in addition. WBAN is very useful emerging technology having immense utilities and benefits in daily life not only for Healthcare but also for Athletic training, Public safety, Consumer electronics, secure authentication and Safeguarding of uniformed personnel. The challenges and open research area discussed in this study will be considered as a source of inspiration for future research directions.

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