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Smart Diagnosis of Orthopaedic Disorders using Internet of Things (IoT)

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Abstract*: Globally, Internet of things (IoT) is recieving a lot of popularity among its users, and it is the most popular new technology in the IT market. A few years back, it is hard to imagine that we can control our home appliances, physical devices, cars and other items remotely with our mobile phones but today it is possible because of IoT. We can instruct our appliances and devices even when we are not physically present there. This article gives the overall view of the Internet of things and also covers a case study of Back pain patients who can be diagnosed using IoT systems. The paper especially focuses on functionality and components of IoT and how it changes our daily life. In today's society, it's use is limited, but as we are moving towards device connectivity, in few years it is used almost everywhere. Treatment of vertebral column disorders remains a challenge for orthopaedic surgeons, neurosurgeons and paediatrics. In the paper, we have tried to analyze how IoT is used in Computer aided diagnostic systems using dataset of orthopedic patients and how an IoT system automatically decide on health of a patient.

Index Terms*: IoT, device connectivity, Computer aided diagnostic, sensors, network, connection, software, hardware, security.

I. INTRODUCTION

The term Internet of things (IoT) can be explained as the interconnection or internetworking of devices like household appliances, vehicles and related devices embedded with electronic circuits, sensors, actuators, motors, networking devices and controlling software which allows devices to establish a connection with each other to collect and exchange data among them. In home by using the IoT system remotely monitor and manage our home appliances and cut down on your monthly bills and resource usage [1]. Every object is identified uniquely as every device has its own embedded controlling software but they are able to inter-operate on existing network infrastructure.

It is estimated that around 30 billion objects are on IoT and its market is about 7.1 trillion by 2020, because of huge public interest on IoT. The term "the Internet of things" was stated by Kevin Ashton of Procter & Gamble, later MIT's Auto-ID Center, in 1999. The IoT allows the object to access remotely on a network, one can control his devices remotely, it allows the objects to be integrated with the computer-based system that allows improving efficiency, productivity, and accuracy and reduces human intervention. As IoT is a sensor and software-enabled system, thus it lies in the class of cyber-physical system.

IoT introduces various new technologies like: smart homes, smart grid, smart cities, smart healthcare, virtual power plants and intelligent transportation. IoT makes our life easy as we generally forgot to switch off lights or to turn off the TV which increases the electricity consumption, when we left for office; it is not possible to turn off lights or TV remotely a few years back but due to IoT now it is possible to control our devices remotely using smart phones. It is suitable for any environment and flexible also, so it has its applications in industries too.

II. HISTORY OF IOT

The concept of IoT was discussed in early 1982, but it became popular in 1999. The ongoing developments in IoT give directions to Massachusetts Institute of Technology (MIT) to design a RFID infrastructure of their institute. Further it was realized that RFID is the prerequisite infrastructure for the IoT Network. For the first time, the implementation of IoT was proposed by using minuscule identifying devices or machine-readable identifiers on the object of the world that would be to transform daily life. The interaction with objects to a person can be changed from remote location based on present needs, according to end-user agreements.

The thought-model was proposed in 2004 for the future connection environment. The model consist of virtual world and mental world, mobile sensor network, and the community of intelligent human made machine at highest level, it supports the cooperatively accomplish tasks and solve problem of globally dispersed users using the network.

III. COMPONENTS OF IOT

As trillions of things (objects) are connected to the Internet it is necessary to have an adequate architecture that permits easy connectivity, control, communications, and useful applications [2]. The IoT is the interconnection of physical devices, so it consist of many components which helps in communication between devices, generally it consist of two types of components namely hardware and software. Here hardware components are physical components that provide the connectivity and provide detailed surrounding information to the device and the software components are that which compute the information provided by the physical components and control them.

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- Hardware Components

- Sensors :

It is the most important hardware component in IoT. Sensor is a device whose primary task is to detect an event in its territory and forward that information to other electronics device. The main components of a sensor are transceiver ,RF modules, power generator, secondary memory. Some of the devices which are sensor based are mentioned as following:

S. No.	Sensors	
1.	accelerometers	temperature sensors
2.	magnetometers	proximity sensors
3.	gyroscopes	image sensors
4.	acoustic sensors	light sensors
5.	pressure sensors	gas RFID sensors
6.	humidity sensors	micro flow sensors

TABLE 1:various sensors in IoT

- Wearable Devices :

The devices which are wearable by the users for controlling the IoT devices and it is generally worn on head, arms, neck, feet, or to or so come under the scope definition for wearable device. Smartwatches are the best example of wearable devices, it not only help us in connectivity with the IoT but also help by allowing access needed for improving productivity. Some of the latest smart wearable devices includes :

- Apple Watch
- Fitbit Versa
- Amazfit Bip
- KardiaBand
- Owlet

In addition to research community efforts, serious business decisions taken by numerous major ICT companies such as, Google, Apple, Samsung, and Cisco have transferred the Internet of Things from conceptualization to reality [3]. Smart glasses allow us to enjoy media and services and are a part of IoT and are the new approach to productivity.

- Standard devices :

These devices are integral part of IoT and used as command center and remotes, these devices are desktop, tablets, and cellphones.

- Desktop :

Maximum control by the user over the system setting then must go for desktop.

- Tablet :

To experience the key features of the computer in a way same as desktop then tablets are used, it acts as a remote.

- Cellphone :

This act as a remote and used only for some essential modifications of settings.

A. Software Components

A number of analysts, notably Cisco and Ericcson (Dave Evans and Hans Vestburg, respectively), have predicted that there will be 50 billion devices connected to the internet by 2020 [4]. There are several software used in IoT for different applications which are embed in the system. These software helps in network connection, controlling, data collection, real-time analysis, and integration.

- Data collection :

The primary task is to control sensing, data filtering, supervise data security and data aggregation. It follows some protocol for real-time, machine-to-machine network connection, then this software is used for collection of data from multiple devices and distributes the data accordingly, and in reverse it distributes data back to devices. All collected data is transmitted to the central server.

- Device integration :

This software is used for device integration to form a IoT based system. The primary task is to cooperate and maintain network connection among devices. These software tools are backbone without them IoT systems will not be formed to allow communication between devices various applications, protocols, and limitations of devices are managed by these software.

- Real-time analysis :

These application convert data into viable action for human analysis that are taken from various devices. To perform automation-related tasks these applications analyse information based on design and settings.

- Application and Process Extension :

These applications helps to create the wider and more effective system by extending the reach of present software and system. For purpose of allowing engineering instruments access or mobile devices these software integrate predefined device, and supports more accurate data collection.

IV. TECHNOLOGY AND PROTOCOLS

The common technologies and protocol of IoT are RFID, Low energy radio protocol, NFC, Low energy Bluetooth, WiFi direct and LTE-A. These protocols allow IoT to networking functionalities in contrast to standard networks of common system.

- **NFC and RFID :**

Radio frequency identification (RFID) is used to allows tracking of individual object, access tokens, secured connection and Near-field communication (NFC) is particularly used for payment.

NFC helps in communication between mobile device and standard device following some communication protocol. Whereas RFID identify and track objects following two ways radio transmitter-receivers.

- **Low Energy Bluetooth :**

In comparison to Classical Bluetooth ,the new low energy Bluetooth consume less energy and cost, with no compromise with the quality.

- **Low energy wireless :**

This technology provide considerably reduced power consumption of IoT device, as sensors and other components of the system drains the energy over long periods, communication links remains in passive mode, thus consumption of low energy wireless decreases the energy consumption and increases the device life.

- **WiFi Direct :**

This device provides end to end connection at the similar speed of WiFi. It removes the need of access point. It does not compromise the connection speed and throughput. It removes the elements of networks that slow it down.

- **LTE-A :**

LTE Advance is an upgraded technology of LTE, it not only increase the coverage area but also decrease its latency and increase the throughput. It provides huge power by increasing its range, with applications in vehicle, UAV, and other similar communication.

V. APPLICATIONS OF IoT

Over the past decade, a flourishing number of concepts and economic shifts appeared such as cloud computing, Internet of Things (IoT), Semantic Web, or still the sharing economy [5]. IoT is the new emerging technology and the is used in almost every areas some of the areas are :

- **Agriculture :**

India play's a prominent role in the agriculture, almost 70% of the population are related to agriculture. . Now a day's modern India uses the technique to improve the quantity and quality of yield. In the rural areas government also provide the financial scheme to encourage to agriculture. In agriculture large amount of machinery used instead of manual labour common use of minerals fertilizers and chemical crop protection against, soil parameter change, in these areas IoT plays an important role in managing these machineries, the smart dairy is one of the best examples of IoT, in which dairy is fully automatic and controlled by the owners using smartphones remotely and also monitoring can be done remotely.

- **Smart Homes :**

Smart home where all the household appliances or devices are enable to connecting and communicate with each other with unsubstantial surroundings. Now a day's various objects are connected to the internet, but it future all of these devices can be in active communication and will be controlled by users form remote location with the help of voice command .The appliances should be installed in such a way that it works on the basis of instruction program provided by their owner.

- **Wearable :**

Wearable devices are the smart devices which facilitate their user with exciting digital features .Examples of wearable devices are Google Glass ,apple, I watch and Fitbit health tracker etc .It has become a great field for investment .many companies like Google ,Microsoft ,Amazon extending the support in this field.

- **Smart City :**

When we say smart city it does not mean that it is the city where people are smart but it means the technologically advance city. Many countries are putting extra efforts in order to make their city smart.

Suppose we are living in a city which is suffering from massive air pollution and in order to remove the pollution from air we installed air purifier machine to purify the air, so this is how we make our city smart. In order to control the crime in the city if government installed such CCTV cameras which not only record the crime but also inform the police instantly by sending an alarm. So these are the factors that needs to be considered in order to decide whether the city we are living in is actually a smart city or not.

- **Smart grids :**

Smart grid is an electrical grid that works on the given set of data .smart grids does not only takes data but it also takes some useful information related to that data so that it can produce some useful information to its user. Smart grids take real set of data from the company or organization, it considered some decision taken by the suppliers and consumers to predict some useful information. The primary principle behind the smart grids is to collect data in an structured way and compare the behaviour of electricity consumers so that efficiency can be improved upon and electricity consumption can be controlled. The smart work on the fashion that it calculate the need of the user according to previous data and supplies the power according to that, thus the wastage of energy can be reduced.

- **Connected car :**

Connected car is the car which connected to the internet with wireless media. Connected car is a smart car that can not only share information with the devices within the car but also it can communicate with the devices outside the car. Connected car provide some extra control to the driver of the car that is usually not found in the normal cars.

Connected car was first made by General motors' in 1996. Connected car hitting up the market slowly it is not popular right now in 2-3 years it became popular. Some of the software giants like Google, Microsoft, Apple are developing the platform for connected car when platform are ready then it is possible that we will see connected car everywhere.

- **Connected Health :**

The primary objective of IoT in healthcare is to empower people to live healthier life by wearing connected devices. The data monitored from these wearable devices will help in personal assessment of individual health and plan strategies to cure the concerned illness. European country has widely accepted the term connected health and due to its huge popularity in the health sector, other countries are also working in this field.

VI. LIMITATIONS

Many technical communities are vigorously pursuing research topics that contribute to the Internet of Things [6].

Apart from rapid advancement's in the field of IoT there are some serious concerns about the limitations of this technology, for example

- **Privacy** :

With help of internet of things we can exchange any information through wireless medium, therefore it is very easy for the hacker to breach the security, for example suppose what if someone knows where you went yesterday or what medicine you take. In a situation hacker change your medical prescription and you take another medicine that can harm you, in such case nobody knows what will happen to yourself. Because that time everybody dependent entirely on the technology here would be the least probability that he would bother checking himself.

- **Compatibility :**

Everybody know very well now a day's there is no international standard for device compatibility. For example some instrument (like: home based appliance), having problem in the connecting with phone or laptop. As we know the apple device does not having the connectivity with other device [7].

VII. Research Contribution

In our paper, we have chosen a dataset build by Dr. Henrique da Mota. The Dataset is available at University of California Irvine's (UCI) Machine Leaning Repository. The dataset contains 310 number of instances and 6 attributes. where 100 patients are categorised in normal category and 210 patients are categorised under abnormal category. This dataset is collected using magnetic resonance images (MRI). Patients of category Disk Hernia and Spondylolisthes patients (both are the diseases that form a major cause of back pain) is are combined into a single class label named abnormal. Treatment of vertebral column disorders remains a challenge for orthopedic surgeons, neurosurgeons and pediatrics. Each patient in this database is represented with six biomechanical attributes:

- Pelvic Incidence (PI)
- Pelvic Tilt (PT)
- Lumbar lordosis angle
- Sacral Slope (SS)
- Pelvic radius
- Grade of spondylolisthesis.

```
In [2]: import pandas as pd
        import matplotlib.pyplot as plt
        import seaborn as sns
```

Figure 1: Libraries used for Data-analysis

```
df = pd.read_csv("column_2C_weka.csv")
```

Figure 2: importing dataframe

```
In [4]: df.info()

<class 'pandas.core.frame.DataFrame'>
RangeIndex: 310 entries, 0 to 309
Data columns (total 7 columns):
pelvic_incidence            310 non-null float64
pelvic_tilt numeric         310 non-null float64
lumbar_lordosis_angle       310 non-null float64
sacral_slope                310 non-null float64
pelvic_radius               310 non-null float64
degree_spondylolisthesis    310 non-null float64
class                       310 non-null object
dtypes: float64(6), object(1)
memory usage: 15.8+ KB
```

Figure 3: Information regarding attributes of dataframe

In [7]: df.describe()

Out[7]:

	pelvic_incidence	pelvic_tilt numeric	lumbar_lordosis_angle	sacral_slope	pelvic_radius	degree_spondylolisthesis
count	310.000000	310.000000	310.000000	310.000000	310.000000	310.000000
mean	60.496653	17.542822	51.930930	42.953831	117.920655	26.296694
std	17.236520	10.008330	18.554064	13.423102	13.317377	37.559027
min	26.147921	-6.554948	14.000000	13.366931	70.082575	-11.058179
25%	46.430294	10.667069	37.000000	33.347122	110.709196	1.603727
50%	58.691038	16.357689	49.562398	42.404912	118.268178	11.767934
75%	72.877696	22.120395	63.000000	52.695888	125.467674	41.287352
max	129.834041	49.431864	125.742385	121.429566	163.071041	418.543082

Figure 4:Statistical information regarding Dataset

In [8]: crr =df.corr()
crr

Out[8]:

	pelvic_incidence	pelvic_tilt numeric	lumbar_lordosis_angle	sacral_slope	pelvic_radius	degree_spondylolisthesis
pelvic_incidence	1.000000	0.629199	0.717282	0.814960	-0.247467	0.638743
pelvic_tilt numeric	0.629199	1.000000	0.432764	0.062345	0.032668	0.397862
lumbar_lordosis_angle	0.717282	0.432764	1.000000	0.598387	-0.080344	0.533667
sacral_slope	0.814960	0.062345	0.598387	1.000000	-0.342128	0.523557
pelvic_radius	-0.247467	0.032668	-0.080344	-0.342128	1.000000	-0.026065
degree_spondylolisthesis	0.638743	0.397862	0.533667	0.523557	-0.026065	1.000000

Figure 5: Correlation within attributes in dataset

```
In [10]: df.plot(kind='box',figsize=(8,8), subplots=True, layout=(3,3), sharex=False, sharey=False)
         plt.show()
```

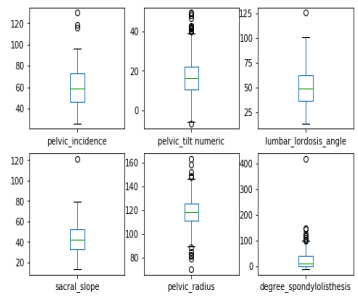

Figure 6: Boxplot for checking presence of outliers in dataset

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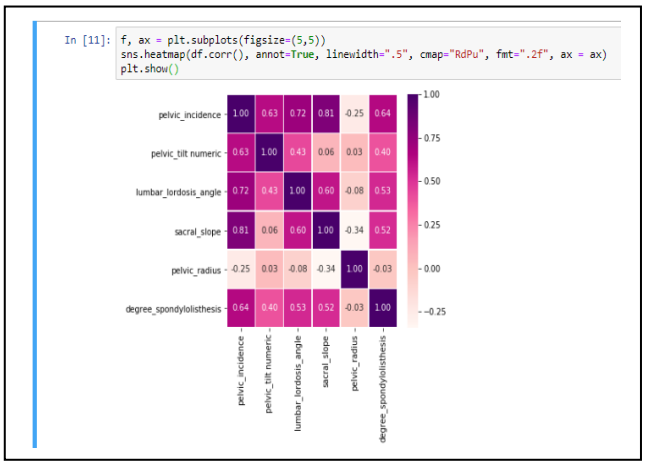

Figure 7: Correlation Map according to attributes in dataset

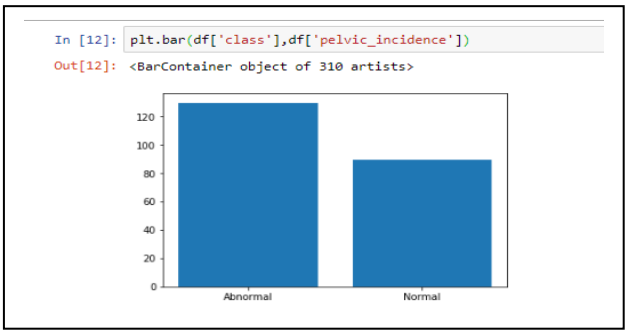

Figure 8: number of abnormal patients are much higher as compared to normal

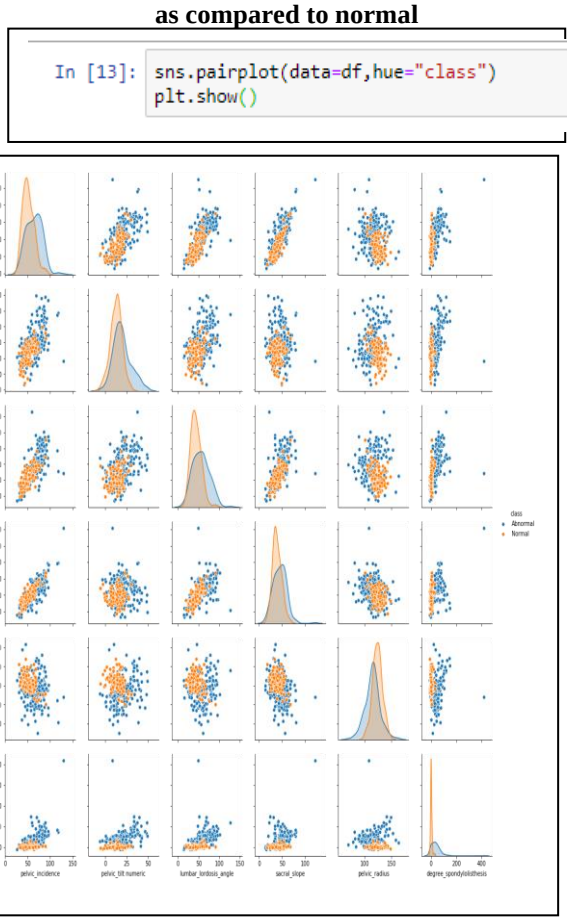

Figure 9:Pairplot

	A	B	C	D	E	F	G
1	pelvic_incidence	pelvic_tilt numeric	lumbar_lordosis_angle	sacral_slope	pelvic_radius	degree_spondylolisthesis	class
2	63.0278175	22.55258597	39.60911701	40.47523153	98.67291675	-0.254399986	Abnormal
3	39.05695098	10.06099147	25.01537822	28.99595951	114.4054254	4.564258645	Abnormal
4	68.83202098	22.21848205	50.09219357	46.61353893	105.9851355	-3.530317314	Abnormal
5	69.29700807	24.65287791	44.31123813	44.64413017	101.8684951	11.21152344	Abnormal
6	49.71285934	9.652074879	28.317406	40.06078446	108.1687249	7.918500615	Abnormal
7	40.25019968	13.92190658	25.1249496	26.32829311	130.3278713	2.230651729	Abnormal
8	53.43292815	15.86433612	37.16593387	37.56859203	120.5675233	5.988550702	Abnormal
9	45.36675362	10.75561143	29.03834896	34.61114218	117.2700675	-10.67587083	Abnormal
10	43.79019026	13.5337531	42.69081398	30.25643716	125.0028927	13.28901817	Abnormal

Figure 10: Dataset in Weka

VIII. FUTURE SCOPE

As we know the growing technology, it has a great scope in present world and also the companies like Google, Microsoft, apple, oracle and many others worked in this area and get popularity by people, so we can say that it is the developing area in IT world. In near future we will see IoT everywhere every device are interconnected and can be controlled remotely. Google is developing self driving car which is the best example of IoT, and it hit the market soon, amazon developed a device which ordered the daily uses things automatically by monitoring which item get short in home, without any human interaction once it is installed. This is the great example of IoT as in this every device of the home like freeze, washing-machine are connected. AI is one of the most important parts of IoT as development is going on in AI, development in IoT also going on. In short, we can say in future we will see IoT everywhere there are not a single device which is not the part of IoT.

IX. CONCLUSION

However IoT is not as much popular in present world but in near future it is in huge demand, but as we know as the technologies increases it also the increases the threat, there may be always the risk of security breach as we discussed. It makes the life easy and comfortable; device became smarter than ever and needs less human interaction. With some negligible risk, it is a great technology for humans in the way of automated and intelligent devices. Each patient of dataset in this paper is represented with six biomechanical attributes namely, Pelvic Incidence (PI), Pelvic Tilt (PT), Lumbar lordosis angle, Sacral Slope (SS), Pelvic radius and Grade of spondylolisthesis. In this work, by incorporating machine learning techniques with IoT, we have tried to find a solution that can significantly help orthopedist to diagnose the pathologies on the Vertebral Column.

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Dr. Latika Kharb, Professor in JIMS, Delhi, India. She has over 16 years of teaching and research experience in IT. She has published more than 84 research papers in reputed international journals including Scopus, Thomson Reuters (SCI & Web of Science) and conferences including IEEE, Springer. She is Convener of many Springer Conferences. She is also Editor of two Book series with Springer.

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