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- dispense a platform for publishing results and research with a strong empirical component.
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International Journal of Engineering and Advanced Technology (IJEAT) covers all topics of all engineering branches. Some of them are Computer Science & Engineering, Information Technology, Electronics & Communication, Electrical and Electronics, Electronics and Telecommunication, Civil Engineering, Mechanical Engineering, Textile Engineering and all interdisciplinary streams of Engineering Sciences. The main topic includes but not limited to:

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Modular Design of Full Body Exoskeleton Suit for Industry, Construction and Military Purpose

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A B S T R A C T

Exoskeleton suits can be considered as a wearable robotic item ,where the main inution is to increase, improve& boost the physical performance of operator/user by a desired margin , it has a great practicality in the present time as it can be implemented in a variety of filed extending from Health sector to industries .The scope of this is to design a full-body,rigid,Active,performance type mobile-exoskeleton prototype, by targeting it as mainly applicable for the Industry sector , Defence sector& Civil-(construction,fire & safety department, etc) Sectors , which has seen to be taking a leap in to this genre .This paper explicates the methodology for the design which was modeled in "Solidworks" and analysys of mechanical strucuture– performed by "Ansys Workbench"& selection of actuation mechanism with a coustomised design which was validated by a series of analysis in "Altiar Flux Motor" , this paper also scrutinize very succinctly the "gait" cycle & its phases ,itsummarise the necessity of the "gait" analysis- which was performed by "Opensim"from which data was acquired for the analysis of designed prototype& for the guidance inactuation of the prototype by prediction & restriction of drive controller valueto the normal gait values during locomotion by "gait assist function",where the actuator control is primarily by the sensing of a series of "Strain guage" belts attached to the users muscles , 4 different control drivers used for actuation out of which for thigh joint the control drive was coustamised , the battery houses 728 high-performance Lithium-ion cells 0f "Panasonic-NCR18650B 3400MAh",for cooling system a common aluminium heat sink was used.the other critical factors which was considered during the designing was cost-effectiveness, minimal maintenance, ergonomic , efficiency and safety of the designed prototype is also pithily considered . the total weight of the designed prototype model was 79Kg & was able to lift & locomote at 1.36m/s with apayload of 258kg.

Keywords: Exo-Skeleton Suit, Human-Gait Cycle, Human-Machine Interface, Robotics,Exosuit, Robotic actuator, Powered suit, Hardsuit, Exoframe.

I. INTRODUCTION

The exoskeleton is a suit that assists the wearer by boosting their strength and endurance.

It also gives the wearer superhuman powers. So, it is perfect candidate for Industry, military and rescue fields. Idea is to design and simulate an electric-powered full-body exoskeleton suit with aim of long battery life, Better controls, weightlifting capacity of up to300 kg& total weight under 60 Kg. In general, manufacturing industries with 30-250kg subassemblies typically use hanger mechanism, cranes, robots, semi-automatic lifters. The initiative taken by the Robo-mate is one of the first propositions made to retain the exoskeleton notion to the production sectors for restricting the manufacuting industries only to Europe& to preserve the employment opportunities in europian countries[14]. For 13 out of 26 industrial exoskeletons, some evaluations of the physical load reductions were performed[15]. Exoskeletons are important machines to decrease the risk factors associated with Stressed work musculoskeletal injuries. At this point, however, several issues hinder acceptance in industrial applications. The main issue is human-machine interaction and implications for standardization[16] According to a study, more than 72% of exoskeleton robots use an electric motor for actuation. Around 20% of exoskeleton robots are pneumatically powered. Hydraulic actuation was utilized by about 5% and about 3% use alternative or hybrid actuation methods[18]. Pneumatic Air Muscles (PAM) actuation is not feasible due to its Precision and control[8].

II. MECHANICAL DESIGN

The consideration taken in the mechanical design was to be simple, Lightweight, Mobile ,Safe, rigid, Ergonomic & the possibility to accomodate, to different operators,. The mingling factors between ergonomic principles and biomechanics of a average human was the crucial criteria that was to be considered. Most designs was found to use passive actuatuion but it was unable to give the weight support which was well needed in our case [12]. Other main feature considered was the design to be "anthromorphic" in nature, which according to authors of[10]&[5].faciliated the actuation or locomotion of the exskelton very well within the human jurisdiction. The software's used: Solidworks 2020 was used to build the CAD of mechanical prototype , and Ansys V16.2 was used to simulate it under static loads conditions and to extract stress component & and angular moment developed at the joints. and analysis when designing.

Human gait data was acquired from the simulation performed on OpenSim. The suit has been developed to fit operator as per the dimensions from Table 1

Table I: 95th Percentile man measurements with max. and min. values

Indicator	Minimum	Maximum	Ideal
Operator weight	58 kg	80kg	68 kg
Height	160 cm	183 cm	170cm
Chest(flexible)	32 in	46 in	36 in
Waist	32 in	38 in	34 in
Foot size(UK)	8	9.75	9

A human model can be considered as the representation dimension & characteristics of human body with according ratio, it will help us to keep a reference to our designs, In Literature there we can see a number of models which can be taken as reference, here in our case we are taking the model from the study of Drillis and Contini [22] ,in which we estimate the dimension of human segments by taking reference to the height such that as show in table II

Table II Dimension refernce for design

Features	%Height
Hand	10.8
Shoulder to elbow	18.6
Elbow to wrist	14.6
Knee to hip	20.0
Knee to ground	28.5

Table II Dimension refernce for design

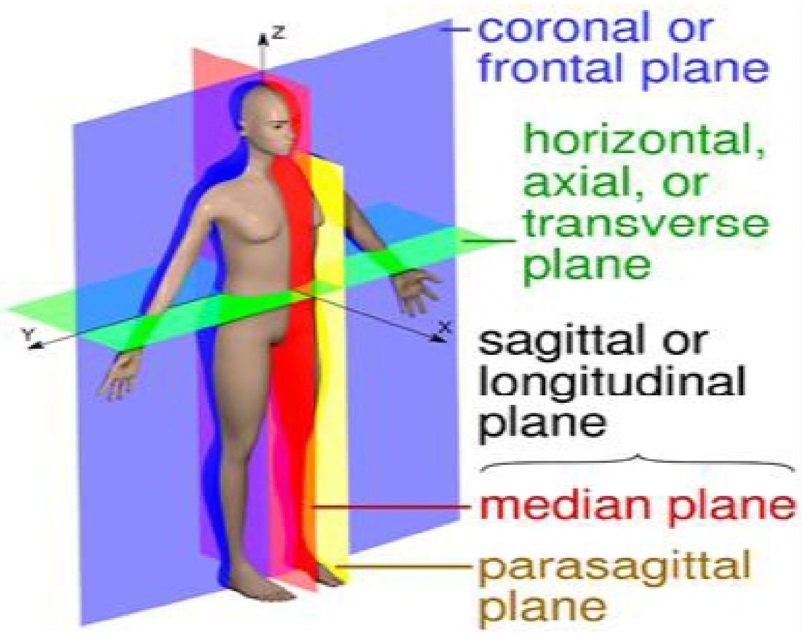

Fig. 1.Human Mannequin with planes.

From the Bio-Mechancs literature of a human locomotion we can observe that there are primarily 3 planes which are , a) the frontal or coronal plane, b) the horizontal axial or transverse plane & c) sagittal or longitudinal plane, by which the 3-dimensional human movements & gait can be represented & here the individual planes dissect the human body as given above , the most important plane here from which we can consider or acquire the angular moment , Load produced & relative motion for the joints & this plane segments is interpreted as longitudinal or saggital plane [5]. Bio-mechanically an human body has a total of around 24-DOF (Upper Body 10-DOF & Lower Body 14-DOF) Musculoskeletal Model while excluding the human head [23] it is to be noted that Generally, when the human body moves under flexion and extension knee and hip joints are active while, ankle joint acts as passive[5], But it will very much convoluted to achieve, So in the final design the design with 7-DOF was selected, when by taking reference to preeding literature reviews the - bio-mechancis of a exoskeleton with 7-DOF(Upper Body 4-DOF & Lower Body 3-DOF) appeared sensible & here as the actuation of exoskeleton is full-active the movement or actuation is restricted by the drive-controller, Such that max-amount of range of actuation is given below – Table –I for Lower Body & Table –II for Upper body

Table III : Motion Range Values Lower Limb Body

Joint	Human Arm	Exoskeleton Arm
Shoulder	-120°to 90°	-50° to 40
Elbow	0° to 135°	0° to 120°
Wrist (rotation)	-90° to 90°	-80° to 80°

TableIV: Motion Range Values Upper Limb Body

Joint	Human Leg	Human Gait	Exoskeleton Leg
Hip	-65°to 120°	-17.5° to 25	-22° to 70
Knee	0° to 160°	-60° to 0°	-80° to 0°
Ankle	-50° to 20°	-14° to 11°	-16° to 18°

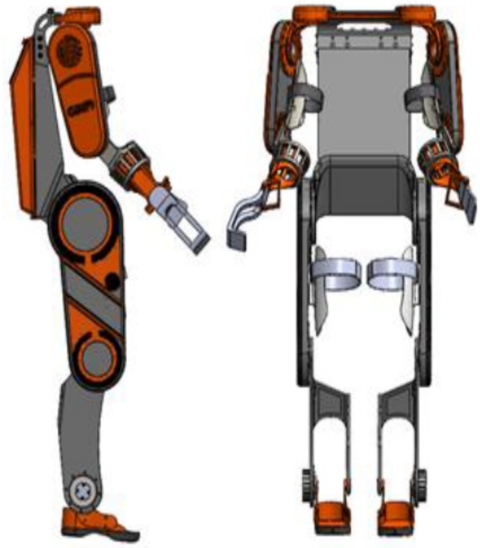

Fig. 2.Exoskeleton Isometric View

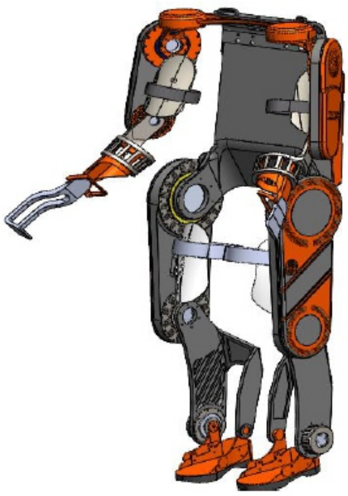

Fig.3.Exoskeleton side and Front view

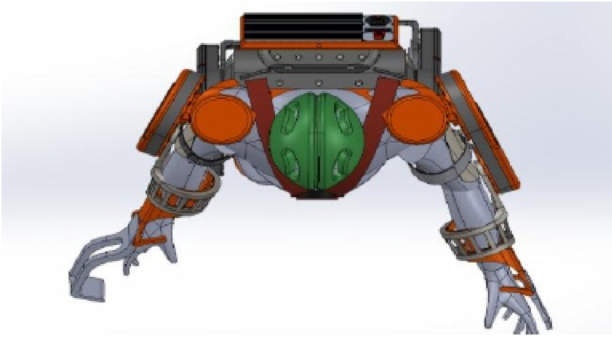

Fig. 4.Exoskeleton Top View

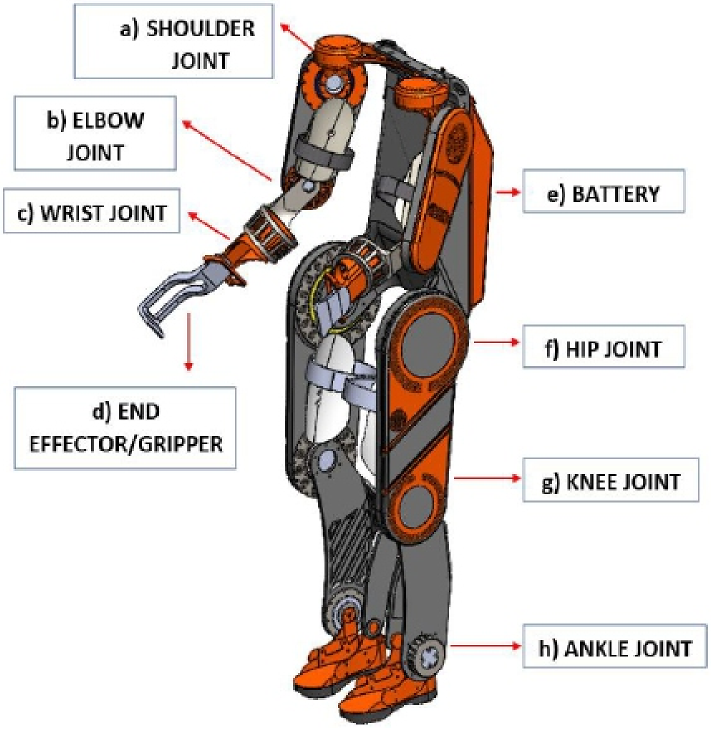

Fig. 5. Overall Structure of Exoskeleton Suit a) shoulder joint, b) elbow joint, c) wrist joint, d) end effector/ gripper, e) battery, f) hip joint, g) knee joint, h) ankle joint.

The muscle activity of the hip muscles/extensor is decreased. The exoskeleton suit creates uncomfortable stress in chest area. During static loading conditions of the forward-bended position, they observed similar reductions of back and leg muscle activity in the with-exoskeleton condition[13]. Hence we choose the suit's bending joint instead of the Spine Lumbar to Hip-Thigh joint. Two variation of the gripper or end effector was designed, is shown in the above figures ,one on the left is the hook type which is the simple and quick solution for carrying an object or product as the hook type end effector will allow you to connect and disconnect the designated areas of the desired object very quickly with ease, the other variation which is on the right is designed such a way that it will act as support for operators/user when operating under low load conditions while using bare hands and fingers for the task , the overall design of end effector is such that it can be detached from the wrist joint so that it is possible for a series of variation of different desired end effector design to be used at different condition

III. HUMAN GAIT CYCLE ANALYSIS

The term gait cycle can be delineated as a series or a sequence of events in process of locomotion for a human which reccurent or persistent in a periodic manner which is showin below figure by a series of phases. The stance step (shown in the R: Stance, Fig. 6) and the swing phase (shown in the W: Swing, Fig. 6) of the human gait cycle are separated. The foot touches the ground during the stance process, the body's mass is stabilised, and the body is pushed forward during the latter stages of stance. As seen in Fig. 6, the stance step consists of five major events:

1. Heel-strike (HS)
2. Foot-flat (FF)
3. Midstance (MS)
4. Heel-off (HO)
5. Toe-off (TO)[3].

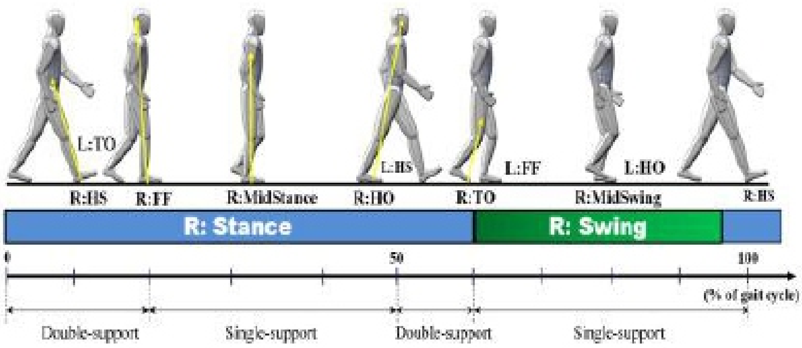

Fig. 6.Human Steps at different stage

i. Heel-strike: The first touch of one foot with the deck, also known as HS or foot-strike, represents the start of the gait .

ii. Foot-flat: The point at which the rest of the foot makes contact with the ground and the leg normally bears the entire weight of the body on one leg.

iii. Midstance: If the centre of mass is immediately above the ankle joint centre, it is called midstance. This is also the point at which the hip joint core is higher than the ankle joint.

iv. Heel-off: When the foot lifts off the ground in preparation for the body's forward momentum, something happens.

v. Toe-off: During the stance process, the last point of touch occurs.

The events of a gait loop occur in strikingly identical cycles and are time-independent. As a result, the period is often represented in percentages rather than in terms of time. The initial HS is designated as 0%, and the corresponding HS of the same foot is designated as 100% (0–100%). The shoulder, knee, and ankle joints all have a range of motion during a typical gait period. Exoskeleton mechanism configuration is optimized by finding minimum work done during a single support phase of a gait cycle[7].

A. The Model Obtained And Simulated In Opensim

Here the gait analysis was done by using the Opensim Gait model "Gait 2392"-which is a three-dimensional, 23-degree-of-freedom computer model of the human musculoskeletal system. (The models were created by Darryl Thelen (University of Wisconsin-Madison) and Ajay Seth, Frank C. Anderson, and Scott L. Delp (Stanford University)) From which the following plot for ankle-joint, Knee joint Hip joint & lumbar bending withrespect to the gait cycle percentage was obtained.

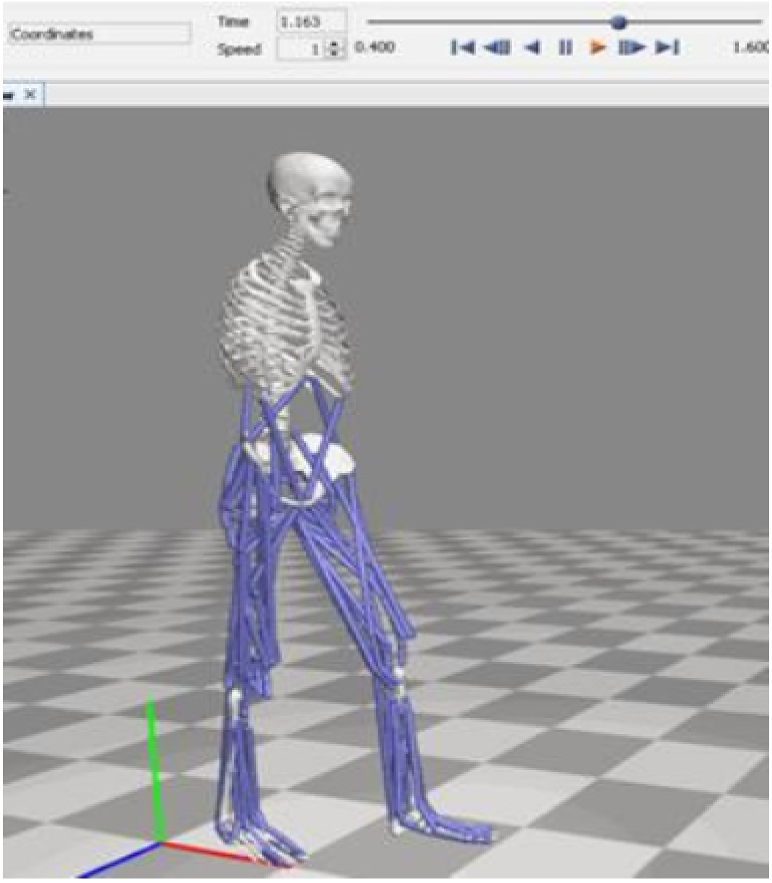

Fig. 7.The above picture shows the OpenSim Gait model "Gait 2392"

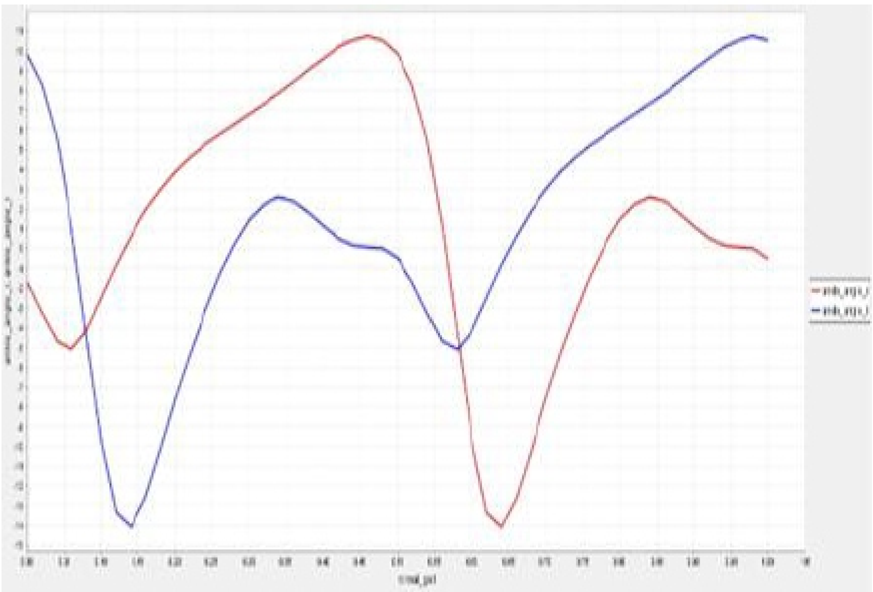

Fig. 8.Ankle graph (in degrees) w.r.t gait %

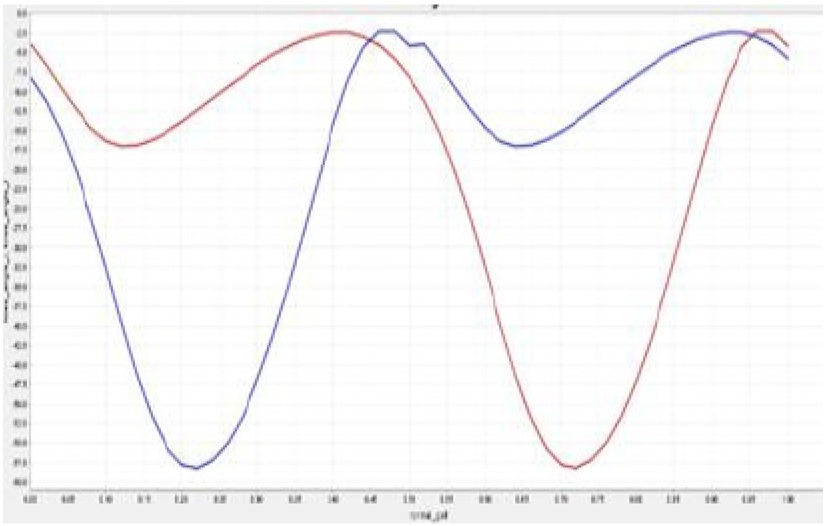

Fig. 9.Knee graph output (in degrees) w.r.t gait %

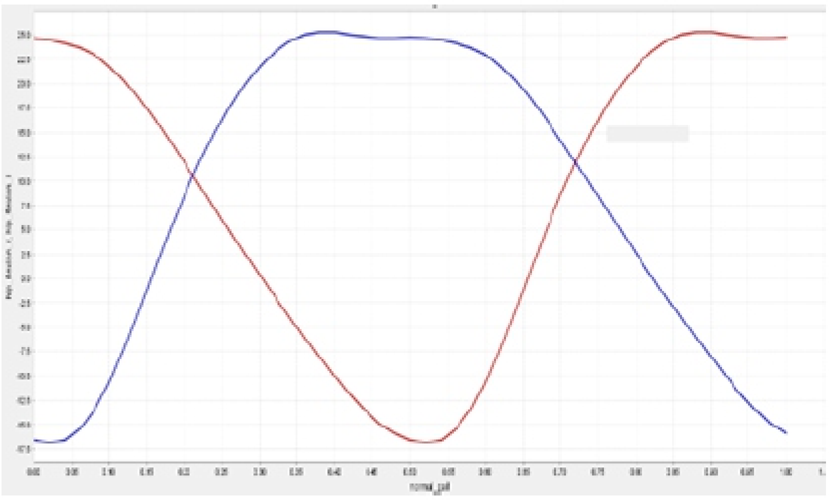

Fig. 10. Thigh angle (in degrees) w.r.t gait%

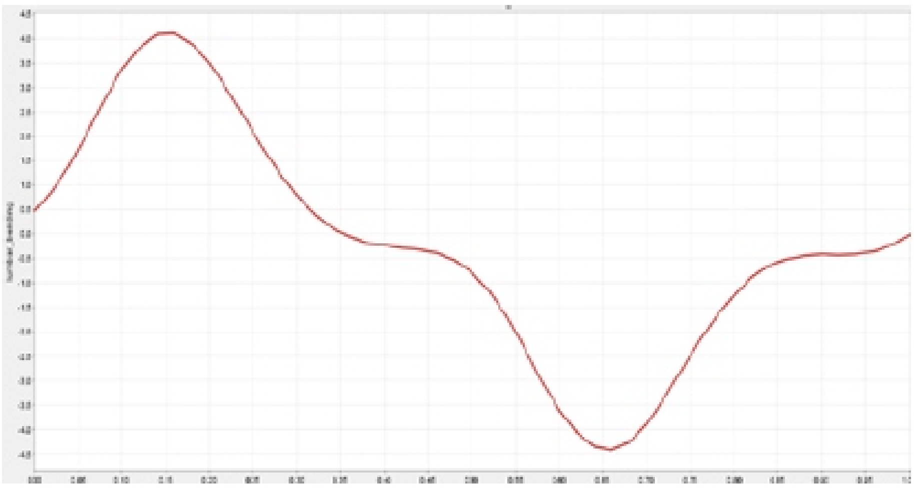

Fig. 11. Lumbar Bending w.r.t gait%

B. Normal Ground Reaction Force

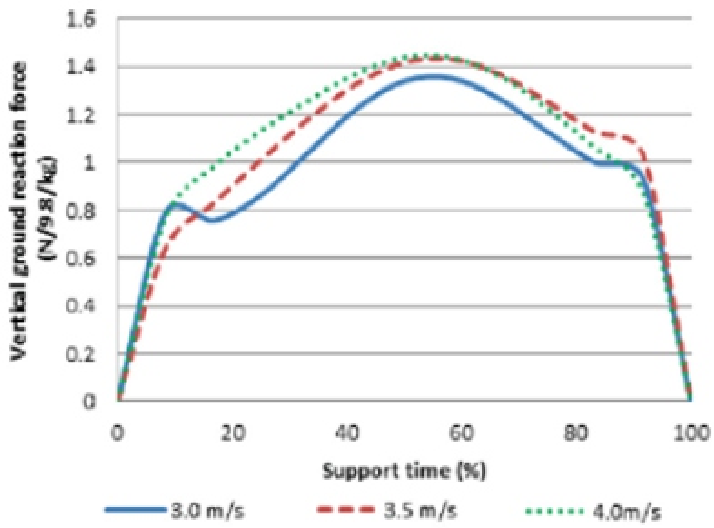

Fig. 12.Ground reaction force[4]

It was found with the reference "Dynamic Optimization of Human Running with Analytical Gradients"[4]for an average human moving with a speed of 3 m/s the reaction force at the foot was around 1.35 times of the body weight (can be seen in above graph Bodyweight% vs Gait %), here in this design also by taking similar intuition we can formulate the normal reaction for robotic exoskeleton suit. So for 300kg payload , with consideration of desired exoskeleton bodyweight of 60Kg we will get the Max-normal ground reaction force as: 1.35 X 360 X 9.8 = 4700Napprox.,the above graph can be inputd for torque calculation in Ansys W.r.t gait cycle

C. Torque and Analysis

The torque analysis was performed only for the lower body part by using the "Rigid Body dynamics tool" In "ANSYS-WORKBENCH". By taking input as the angular data and Normal reaction force data shown above. We were able to acquire the torque generated at the Main three joints in the lower body – (hip, knee& ankle) and the following observations were made.

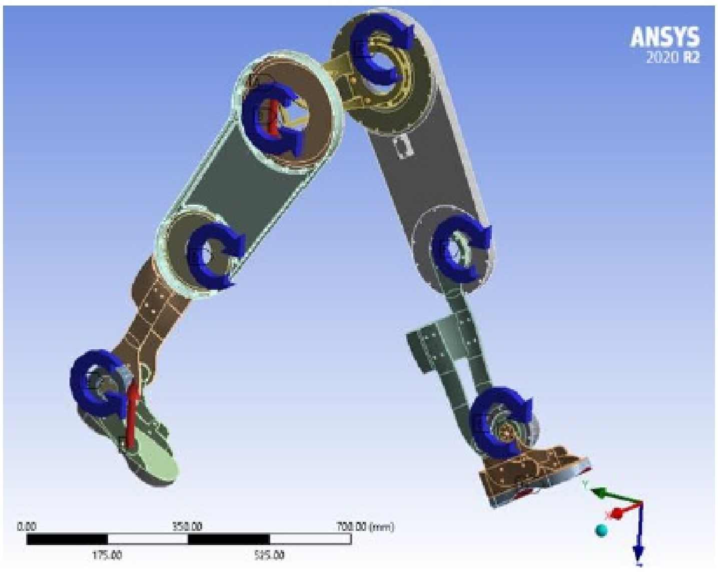

Fig.13 Illustration of Moment simulation on Ansys Work-Bench-Rigid-body dynmics

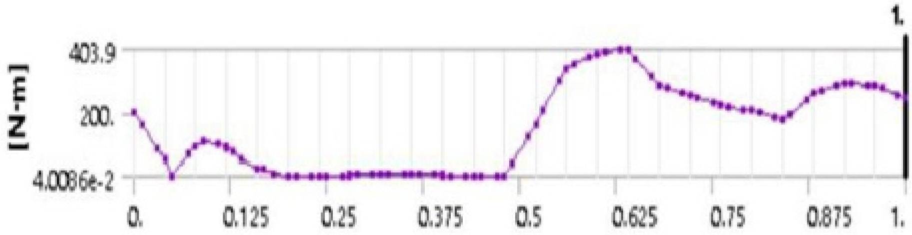

Fig. 14. Ankle Torque Analysis

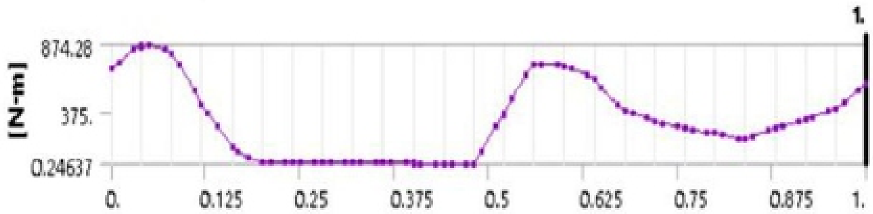

Fig. 15.Knee Torque Analysis

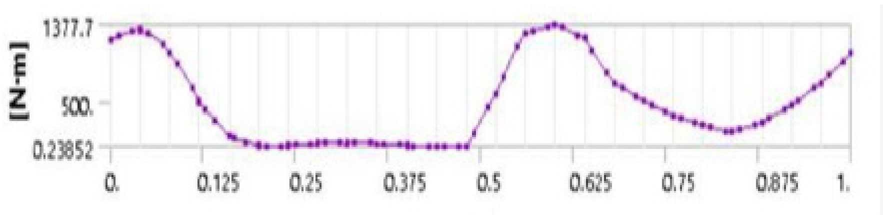

Fig. 16.Hip Torque Analysis

It was found that Max moment developed was 404Nm,875Nm &1377Nm for Ankle, Knee & Hiprepectively.. It was found Similar to our study and simulation the tendancy of the exoskeleton to get the highest stess or pressure at the trunk or back which is then followed by thigh then shoulder. [19]..Gait assist function , From the gait data the degree of actuation during the locomotion in a normal gait can be predicted , this pre-eminence factor can be used as to reduce actuation lags[9] This same notion cannot be used in the upper body as the event occurring in upper body Is not repeatable or dependentable any caertain locomotion phases. similar to gait cycle[18].

IV. STATIC STRUCTURALANALYSIS

The static structural analysis was performed on the exoskeleton suit to verify the structural strength of the different components used in the suit such as parts between elbow to shoulder, elbow to wrist, thigh, shoulder and back. The stress was evaluated by ANSYS software by considering various boundary conditions such as forces, torques and reaction forces from the motor and human gait analysis.

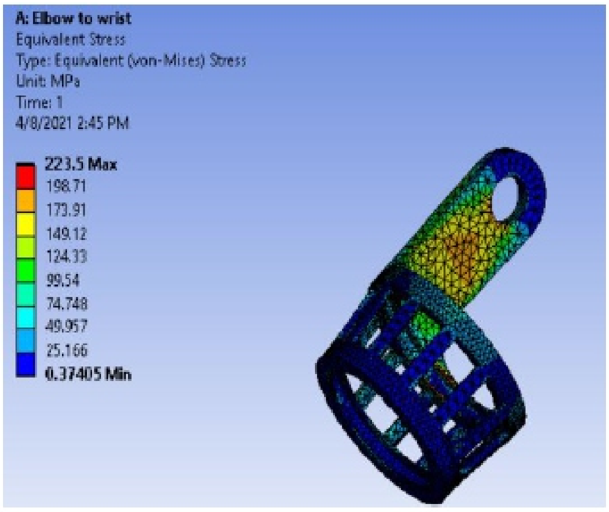

Fig. 17.Equivalent Stress of Elbow to Wrist part

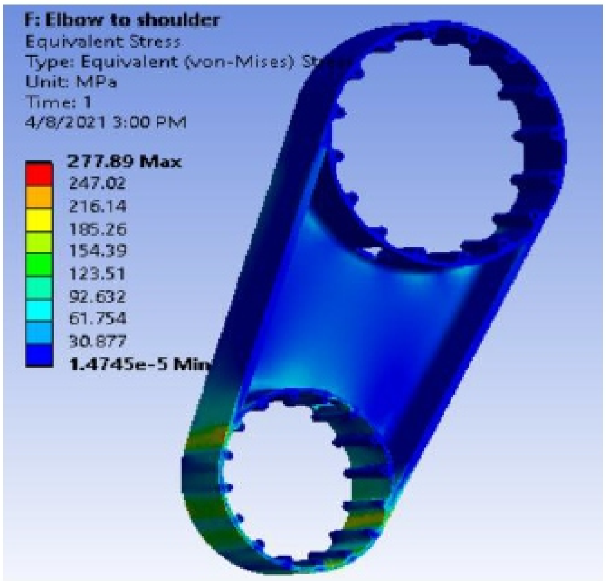

Fig. 18.Equivalent Stress of Elbow to Shoulder part

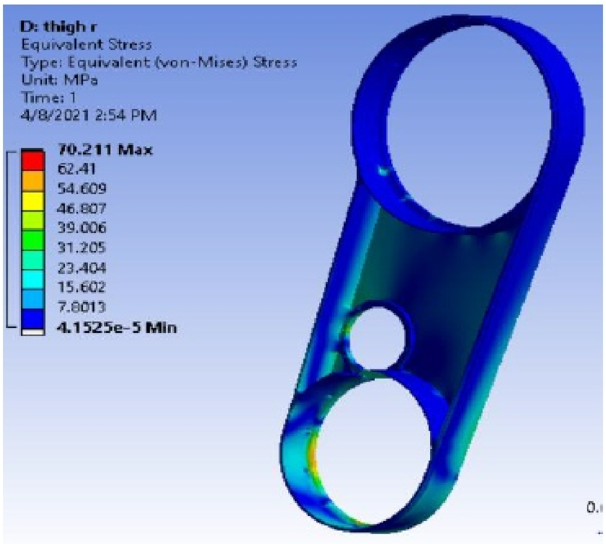

Fig. 19. Equivalent Stress of Thigh part

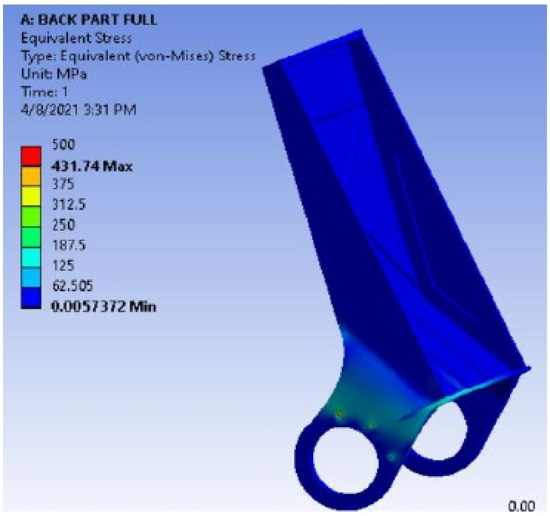

Fig. 20.Equivalent Stress of Back part

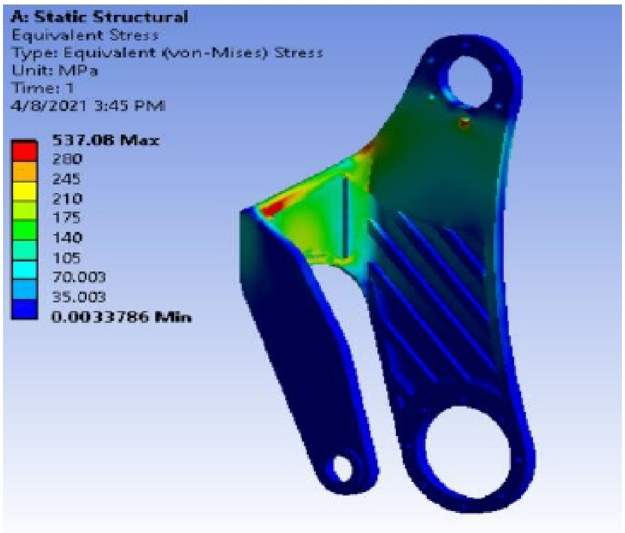

Fig. 21.Equivalent Stress of Knee to Ankle Part

V. BEARING SELECTION

Bearings are the most essential components for the movement of joints in our suit. To withstand 300Kg payload and also compact sizing, bearings of Light series 618xx/67xx bearings are integrated into Motor I/O mounts.

Table- V: Bearing Selection			
Bearing	**Dimensions**	**Static Load (kN)**	**Joint**
6730	180*150*16	41	Thigh
6718	110*90*10	17	Knee
2x 61906	47*30*9	4.6	Ankle
61816	100*80*10	11.2	Shoulder
61810	65*50*7	6.8	Elbow
VB035CP0	105*90*8	7.97	Radius & Ulna

For Planetary Gearbox purpose bearings used are 6704, 6705, 6706, 6707, MR106zz, 61804, 61805, 61808.

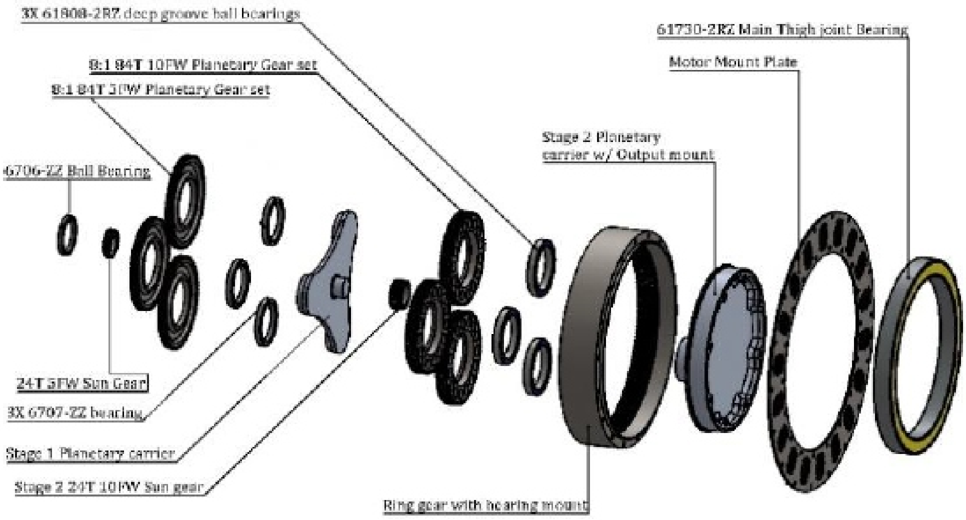

Fig. 22.Bearings in gearbox and Actuation joint

"Fig. 22" represents exploded view of actuator and almost all bearings of exoskeleton suit is housed in planetary gearbox and bigger bearings are only used in joints to counter radial and axial loads.

VI. MOTOR DESIGN

The design used flat high power density EC-motors combined with flat Harmonic Drive gearing. This allows a very compact electro mechanical drive and are directly installed at each joint [17]. Harmonic drives are not suitable for high loads and are expensive, hence we use planetary gears inside motor's core to decrease its size. Reduction gears are mostly used when relatively high torques are required with small and lightweight motors. However, its demerits are: achievable speeds are reduced, and output friction and inertia are greatly amplified. The result is very small control bandwidth, which limits performance during dynamic tasks. Force and torque sensors only partially mitigate the above restrictions, as they increase weight, cost and complexity. Hence the motivation to research sensor less solutions[20]. Our designed motors need to be Hollow disc for high rpm and high Torque.

- Factors Considered during Motor Design
- Stall and low speed High Torque
- On-Load high Speed
- Damping control
- Position control
- Efficiency
- w/ & w/o Cooling
- Bearing Integration
- Planetary Gearbox
- Service life
- Braking control
- Spring control.

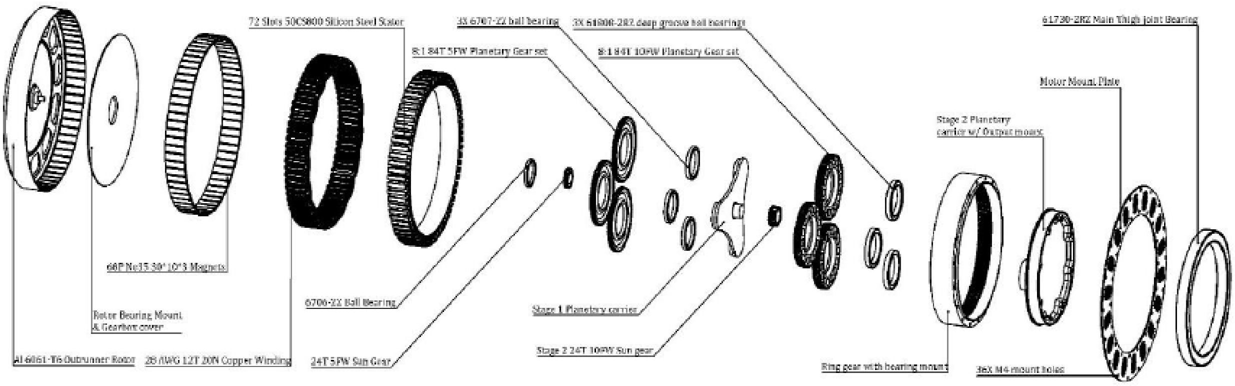

Fig. 23.Motor Design Exploded View

• **Stator:** A 72 Slot Silicon steel (50CS800) Core is used as stator, due to its iron loss of only 4.98W/kg and magnetic flux density 1.55T. 28 AWG motor winding copper is used in windings with 12 Turns of 20 wires in Hand so that it can pass currents upto 350A. This is for 24040 motor, other motors have similar winding Configuration and materials.

• **Rotor:** Outrunner rotor is used because it provides space for planetary gearbox which can be fitted inside the stator. Neodymium N35 magnets are used of various sizes from 8mm to 30mm with common thickness of 3mm. Instead of its weaker Remanence (1220mT) than N52 grade magnets (1480mT), it is used due to availability in various sizes and cost.

• **Gearbox:** It is most important part of our Actuator as it is used to increase torque, but in this exoskeleton to lift 300Kg a huge amount of torque is needed. So each motor has 2 stage planetary gearbox to provide gear ratios upto 72:1. This gearbox is placed right behind the main bearing into the stator's hollow space.

Table- VI:Planetary gearbox Configuration

Motor	Ring-Planet-Sun Teeth	Module – Face Width	Gear ratio (1 Stage)
11040	127-55-17	0.5-6/10	8.5
14540	100-40-20	1-6/8	6
17530	108-45-18	1-4/8	7
24040	192-84-24	1-5/10	8

The materials used for Gears is 40CrMnmo4. 1st stage carrier is made up of EN353 Steel billets. 2nd Stage carrier/Output mount is made of Aluminum 7075-T6.

VII. MOTOR SIMULATION

As main motors are custom designed BLDC for exoskeleton application, it is very important to optimize its parameters by setting different configurations, calculations and materials. Due to unavailability of high torque motors with precision control, these motors are designed and simulated in Altair FluxMotor 2020 software.

Table- VII: Motor performance data

Motor	Rpm/V (Kv)	Torque (N-m)	Load rpm	Current (A)	Power (kW)
11040	170	12.21	7550	89	4.3
14540	150	17.97	5750	118	5.7
17530	90	22.39	3400	147	7.1
24040	120	39.85	6000	353	17

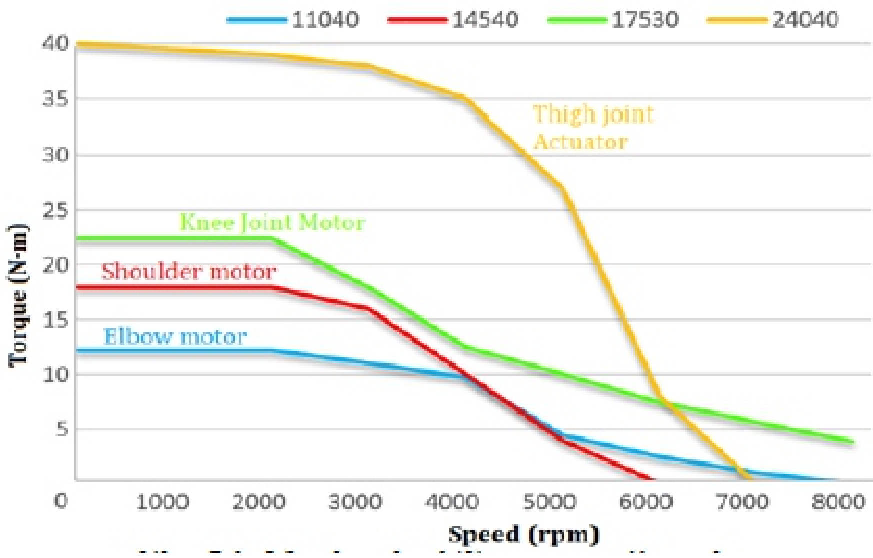

Fig. 24. Mechanical Torque vs Speed

As noticed in above graph Thigh and shoulder motors have significantly high torque at low-medium speeds, but Knee and Elbow motors are designed to outperform at higher speeds insimilar way to human movements.

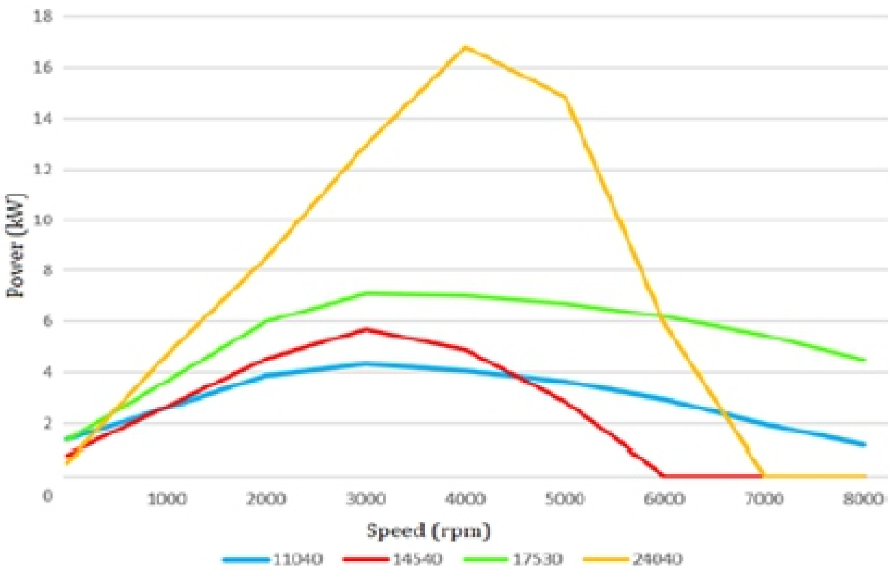

Fig. 25.Apparent Power vs Torque

This graph has data of 17530 90Kv motor which depicts the operation of motor at torque and speed w.r.t time. Short term operation is considered without cooling for 2-5 seconds and with cooling for 10-18 second. Other motors also boast a similar kind of curves but only difference is of torque and speed data. Motor's non-operating region is also motors working region but it is only used for absorbing shocks, damping and spring action of joints. Very similar characteristics which is observed in human movements.

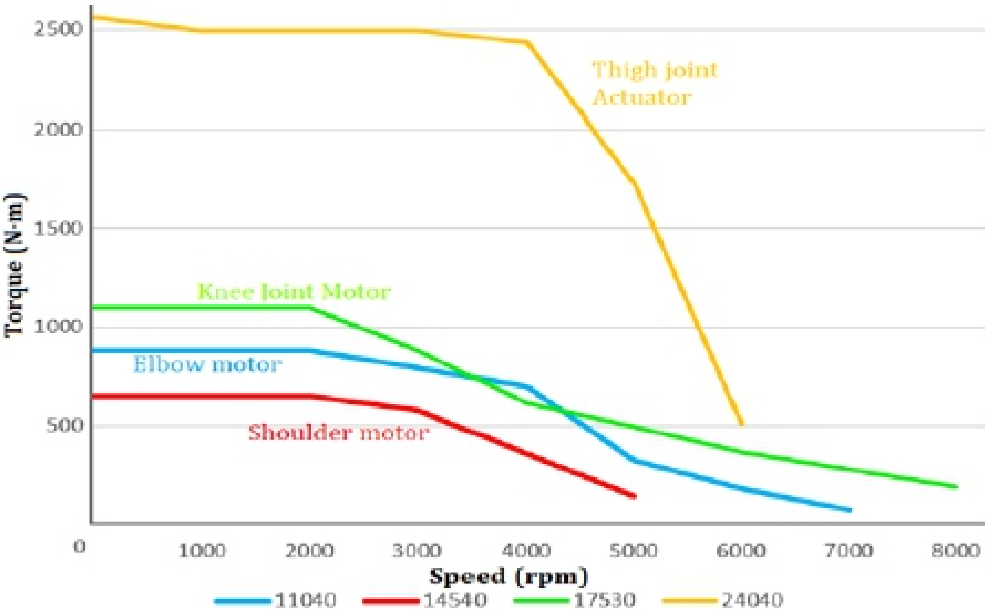

Fig. 26.Torque-speed curves with gearbox

Thigh joint needs very high torque due to its effective distance from ground and also these motors support whole body weight, Hence while lifting an object thigh-hip actuators are under maximum load. Whereas shoulder has motors in 2 axis one of which is front-back movement which has lower torque and other is left-right movement which uses same motor as Elbow joint uses.

Table- VIII: Actuators data with gearbox

Motor	Gear Ratio	Peak torque (N-m)	Cont. torque (N-m)	Speed (rpm)
11040	72:1	879	684	105
14540	36:1	647	540	160
17530	49:1	1097	740	69
24040	64:1	2550	1408	94

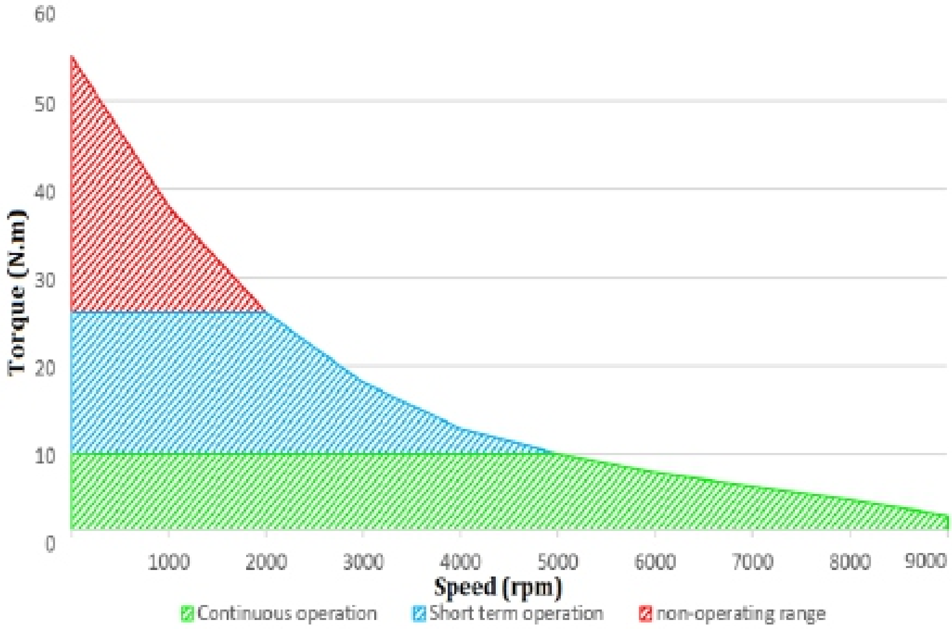

Fig. 27.Analytical graph of motor operation

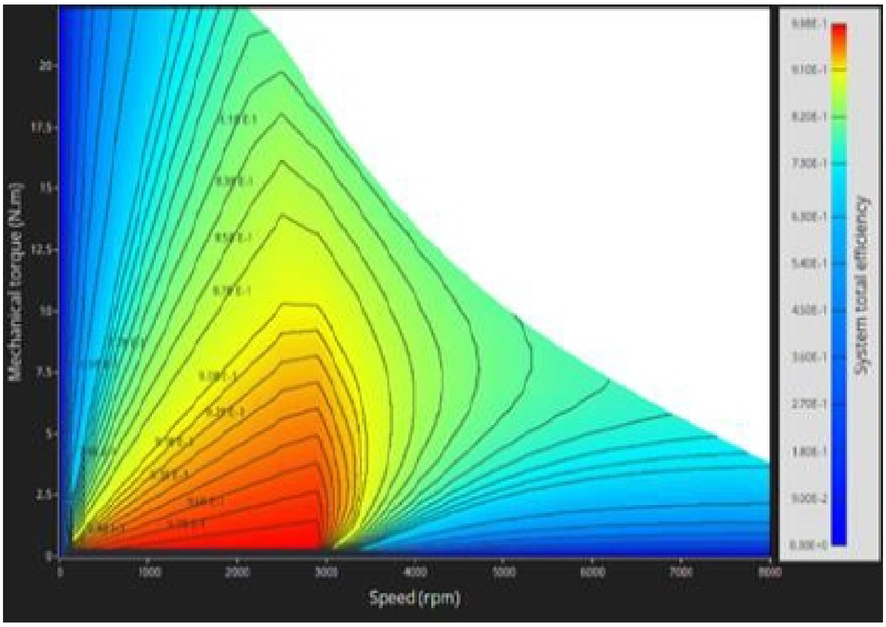

Fig. 28.Efficiency plot on Torque-speed curve

According to simulations, these 17530 motors can operate at 0.98 efficiencies buy at very low torque and low speeds. Carefully analyzing data motors would operate between 0.73-0.88 for most of their loading conditions. During walking without load motors can achieve more than 0.94 efficiencies.

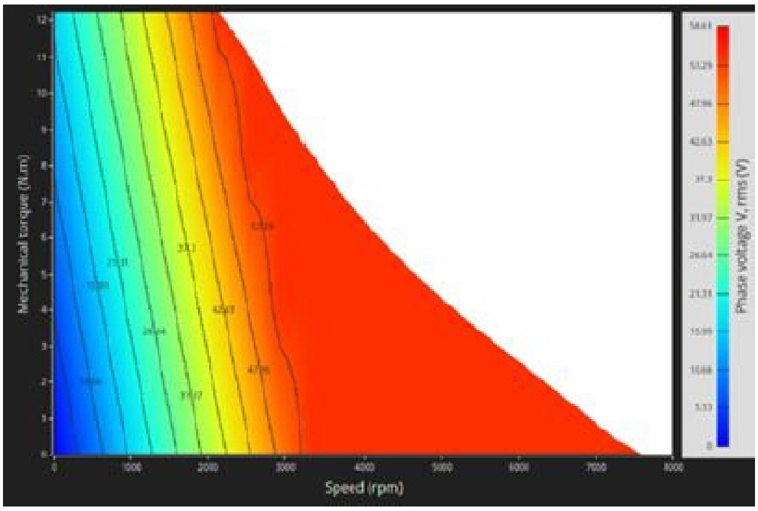

Fig. 29.Phase Voltage plot on Torque-speed curve

This data of 11040 motor shows the voltage required for motors on the torque-speed area. Most of the time motor would be running on 42-55 volts. Similar characteristics are also observed in other motors too.

VIII. CONTROL SYSTEMS

A BLDC motor requires a motor controller to run the motor and hence they are widely used in high-performance machine applications. Generally, they are available for speed control but to be used in robotics speed controllers should work on position control. The major Issue with robotics position control drivers is their Size and weight. This Exoskeleton used speed control drivers which were designed for UAVs and aerospace use. This saves weight and Space.

Table- IX: Controller Configuration

Motor	Joint	Controller	Control modes
11040	Elbow, Shoulder Y	ODRIVE V3.6	Position, Velocity, Current
14540	Shoulder Z	FSESC6.6	DC, FOC, BLDC (sinusoidal)
17530	Knee	16S 200A VESC	Velocity, current, voltage, power
24040	Thigh-Hip	Custom 400A BESC	Velocity, Current, Voltage.

Table- X: Controller Specification

Controller	No. of Motors	Voltage (V)	Max. current (A)	Cont. current (A)
ODRIVE V3.6	2	12-56	100	60
FSESC 6.6	2	8-60	400	100
16S 200A VESC	1	14-75	300	200
Custom 400A BESC	1	36-150	400	250

- **Custom Controller:**

A simple four-layer design of Controller (refer Fig. 28 & 33), to meet the power requirements of Thigh-Hip joint 24040 motor. As the motor operates on 48V 350A current, there was no other Controller in the market to meet these requirements.

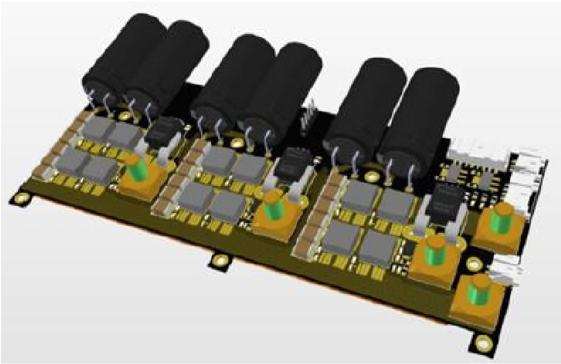

Fig. 30. Custom 400A BESC

- **Main Parts Used:**
  - o IPB044N15N5 150V 174A 4.4mR MOSFET
  - o UCC27714 600V 4A half-bridge driver
  - o ACS758 ±200A hall current sensor
  - o WP-SHFU REDCUBE Terminal M6 250A
  - o 4.7 uf 200 Vx7r ceramics
  - o 560 uf 160V aluminium capacitor

Figure 31:16S 200A VESC

Fig. 32. FSESC 6.63

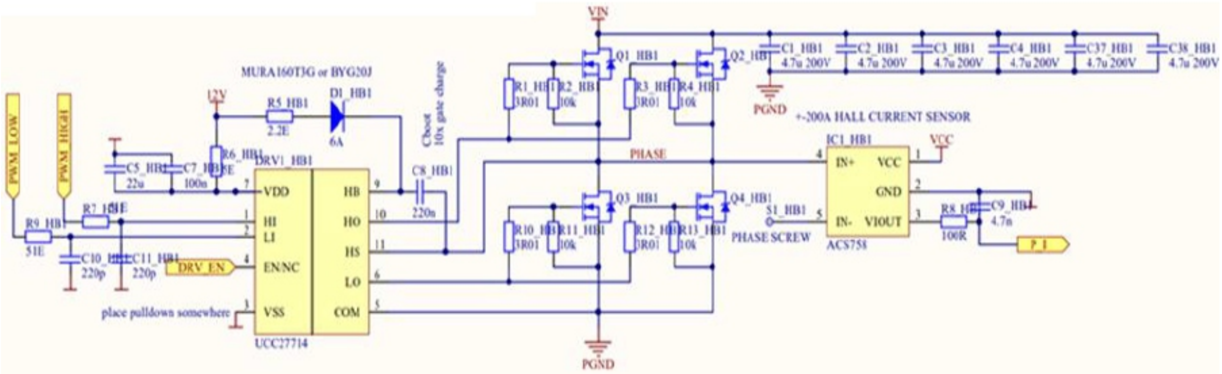

Figure 33:BESC Drive Schematics

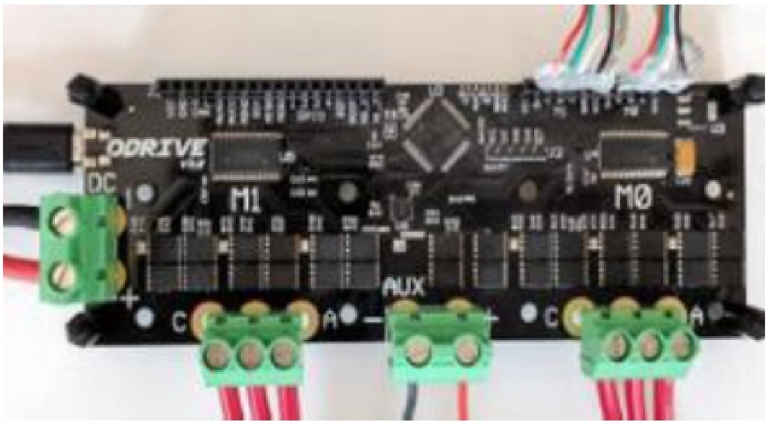

Fig. 34. ODRIVE V3.6

Especially, to perform in position control there are Hall Sensor, rotary encoder, Gyroscope above the rotor to log position of rotor in Arduino motor control unit which uses that data externally to send signals to motor controllers to either increase to decrease speed. It also used PID control for damping, spring modes of actuators. In other driver boards it is done externally but using ODrive controllers it was possible to give precise and fast control to elbow and shoulder actuator.

IX. BATTERY

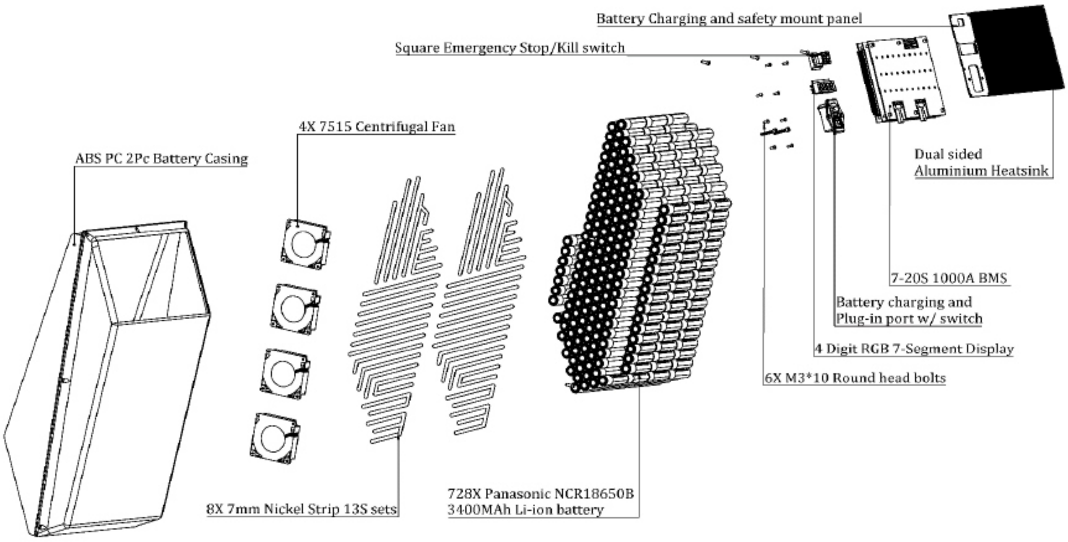

Fig. 35.Battery exploded view drawing

The heaviest component of the exoskeleton is a Lithium-polymer battery weighing 38 Kg. It is designed to last exoskeleton suit for 6 hours of continuous operation. It houses 728 high-performance Lithium-ion cells from Panasonic (Panasonic NCR18650B 3400MAh). The construction of this battery is simple, easily detachable, Water & Dustproof, Plug-In operation makes this bot suitable for manufacturing industries.

Table- XI: 18650 Li-ion cells in market comparison

Battery	Capacity (MAh)	Discharge current (A)	728 cells Weight (Kg)	Cost per cell ($)
SONY VTC6	3000	20	33.92	2.15
SAMSUNG INR1865030Q	3000	15	34.94	2.4
Panasonic NCR18650B	3400	10	33.49	2.45
LG 18650 MH1	3200	10	35.67	2

Calculations:

During holding a weight above the head, the suit resulted in a decrease in muscle activity for the Biceps Brachii (30–70%) and the Trapezius pars transverse (40–70%). This result shows Suit's potential for reducing the physical load on the shoulder and arms for a large range of occupational activities including dynamic lifting and carrying, static work in forwarding bent posture and overhead work[16]. In worst-case scenario, loading exoskeleton suit at 300kg would consume 500A in all motors combined.

No. Cells in parallel = 728/13 = 56 cells.
Total Output Current= No. of cells * Discharge current
Required discharge current = 500/56
= 8.9 A

Meeting these requirements, we found that only a few selected cells can provide higher capacities.

So battery pack configuration is 13S 56P Lithium-ion battery using Panasonic batteries.

Total battery capacity = 56 P cells * 3.4 Ah
= 190.4 Ah
Total battery voltage = 13 S cells * 3.7 V
= 48.1 V
Voltage when 100 % charged = 54.6 V
Voltage when 20 % charged = 42.9 V

Below 20 % cells start to die and never recharge again. These batteries would last up to 800 Cycles.

- **Battery specifications**
  - Nominal Voltage: 48V
  - Capacity: 190 Ah
  - Discharge current: 560A
  - Charging current: 100A

- 1Life cycles: 800+
- Weight: 38 Kg
- Dimensions: 542*300*155 mm

A. BMS

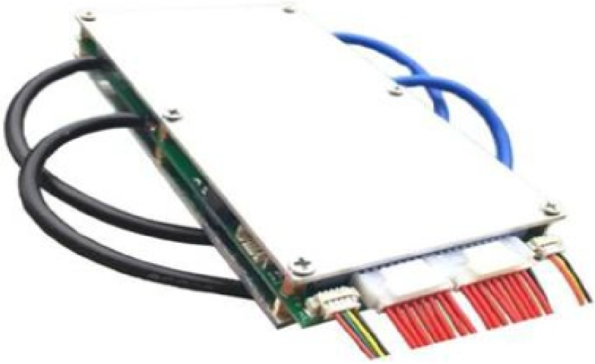

Fig. 36. 7-20S 1000A BMS

This battery uses a BMS which can hold up to 20S and discharge currents up to 1000A. For the Modularity of these robots, several attachments can be loaded on this suit, so the battery management system needs to be of higher discharge current to be able to supply power to attachments like Launchers, Winch, Bucket, jackhammer, Segway, etc.

This is a very standard BMS especially made for small electric Cars, 7-20S 1000A BMS is generic and supports up to 1120 Batteries.

B. Cooling System

As per the current rating of this battery, it is very important to keep the battery cool to prevent cells from leaking and bursting out, which would eventually damage the overall exoskeleton. This exoskeleton uses a common heat sink for Cells and BMS which has 10*1mm fins.

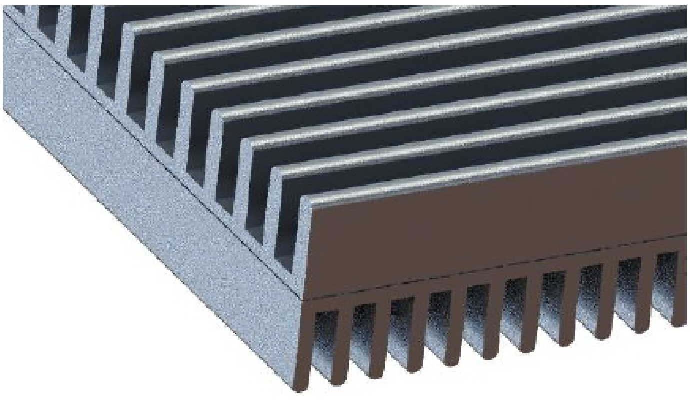

Fig. 37. Aluminum heat sink profile

This battery has 2 layered Aluminium heat sink. The fins are vertical inside the battery and in a horizontal direction outside the battery. Inside the hot air from calls and BMS automatically rises upwards and Cooling fans are used to increase the turbulence and airflow inside the battery. Both heat sinks are connected by thermal paste for better thermal conductivity. 4* 7515 5V Centrifugal fans actively create an airflow inside the battery.

C. Charging and Safety Panel

Fig. 38. Main Battery

This battery has a Control panel at the Back-Top position for easy access. On the Control panel, it has a 220-240V 16A Plug which will be used for charging and Plug-in operation. A 4-Digit 7 Segment display is used to show battery status and capacity. A very important component is Red button Kill switch which is used for safety concerns so that externally this exoskeleton's power supply can be cut off in case of malfunction, fire and emergency.

X. ELECTRONICS

This suit uses control methods ofpHRI signals as control inputs, and the representative methods are force control, master-slave control, and pre-programmed control[6]. The Exoskeleton electronics controller is based on a complex sensor's system which enables to calculation force and pressure applied by the operator, to recognize his intention and properly manipulate the actuators and limbs of the Exoskeleton[14].A strain gauge integrated into each Belt provides the force measurement. Each strained section on the belt as an elastomer to sense strain[21].

A strain gauge on support belts senses the force of human movements inside the skeleton. Using 5 strain gauges on each side provide sufficient data of force in all 6 directions, using vectors the exact direction of force is calculated in the Arduino sensor unit.

Fig. 39. Strain gauge belt

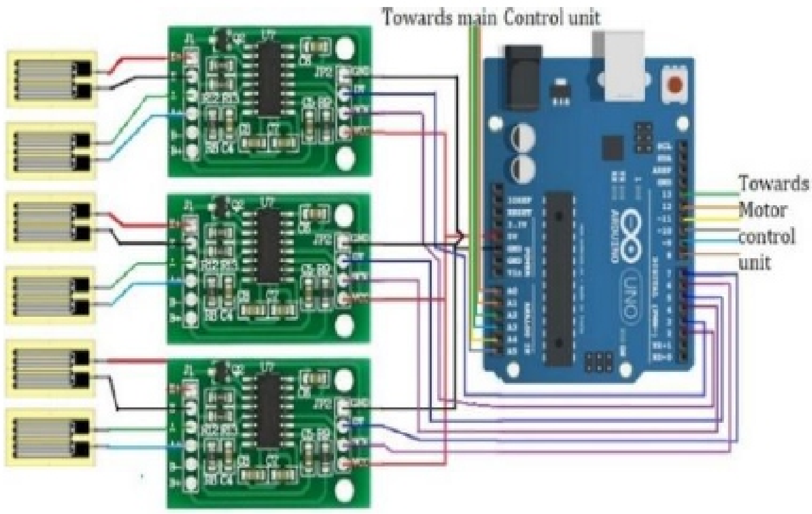

Fig. 40. Arduino sensor unit

There are in total 6 Arduino sensor unit each of them connected to 12 strain gauges and 6 strain gauge amplifier. The resultant force of 6 strain gauges is calculated in Arduino UNO and the final 1 direction, Force, Speed data is sent to the Motor control unit. Also, the Main control unit takes data and matches it with gait cycle curves if the data is within 10% range the motor control unit will work seamlessly, and if not it will immediately send signals to get the correct information and stop exoskeletons functions.

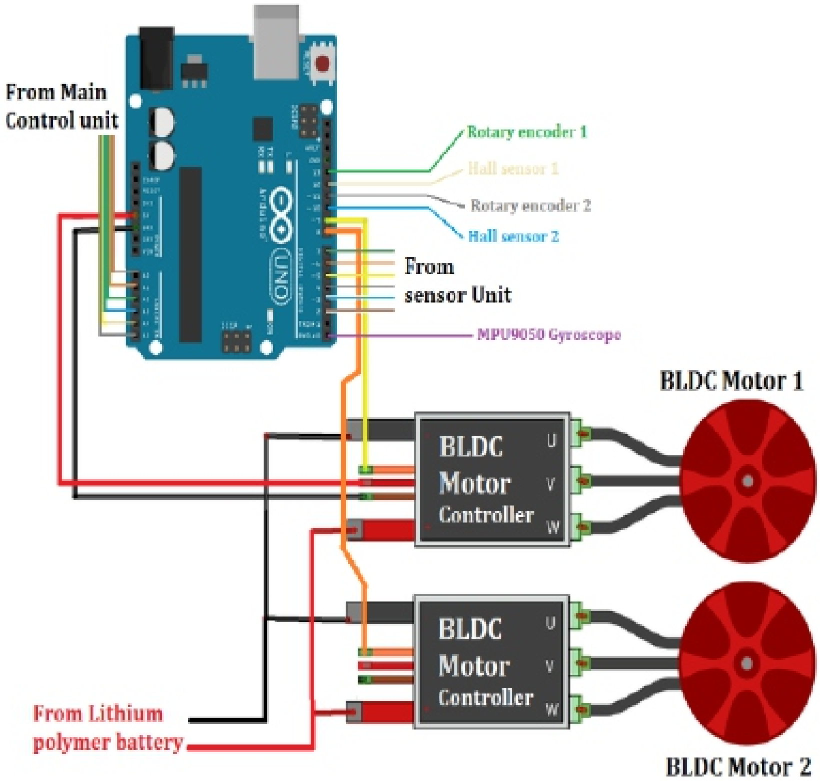

Fig. 41.Arduino Motor control unit

Fig. 41, It is mainly used to get data of linkage position, motor position, motor speed control and the main function of the Motor control unit are to control the motor by position. It is connected to several different sensors and only 2 main motors. Also, it receives data from the Sensor unit and main control unit.

Table- XII: Components in electronics

Component	No's	Location
Arduino mega	1	Main control unit
Arduino UNO	8	The sensor unit, Motor unit
Rotary encoder	10	Motors
Hall sensor	10	Motors
Strain gauge amplifier	33	Thigh and arm assembly
Strain gauge	66	Support belts
Connecting wires	-	Multiple locations
MPU 9050 Gyroscope	9	Every link of the exoskeleton

The Slave controllers measure the joint angle and speed, the force sensors of the lower and upper arm, the force sensors installed in the Velcro belts and abduction-adduction position measurement systems. The high-level control system relies on the controller. The control system calculates the proper value of the supporting torque of each joint and sends these reference values to the joint controllers. Each Controller can control up to three Actuators. Furthermore, the processor communicates with the battery management system (BMS) in Battery. The BMS observes the cells currents, voltages, temperature, calculates the delivered energy and communicates with the main Controller also via the CANOpeninterface[17].

XI. MECHATRONICS INTEGRATION:

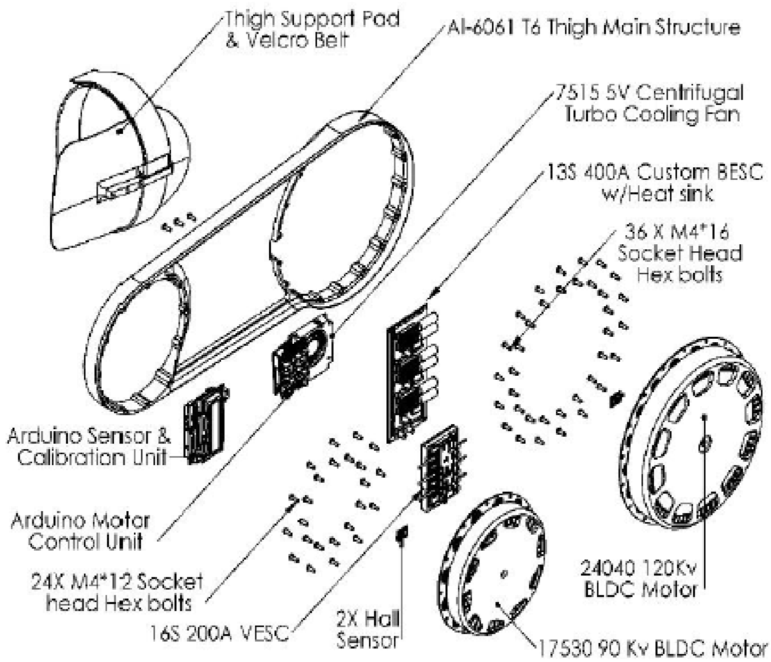

Fig. 42. Exploded isometric view of Thigh link

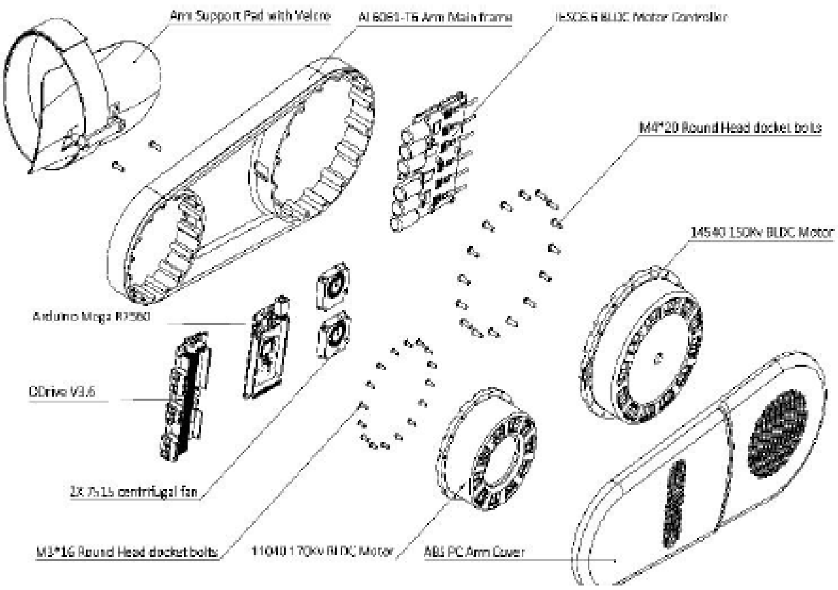

Fig. 43. Exploded isometric view of Arm link

All power electronics components are placed in this for unified cooling of full inner thigh there are many small holes on covers and the 7515 Cooling fan takes care of pumping air inside the thigh. Using this design made it possible to reduce costs, weight, better cooling, easy reparability.

XII. PERFORMANCE SCENARIO:

Requiredtorque :

1.)Static Condition-LifitngScenario : In static condition lifting an object is performed by bending forward the exoskeleton by the actuation of knee & Hip Joint, in lower body ,Shouldr& elbow joint in upper , the intuited posture is shown below figure:

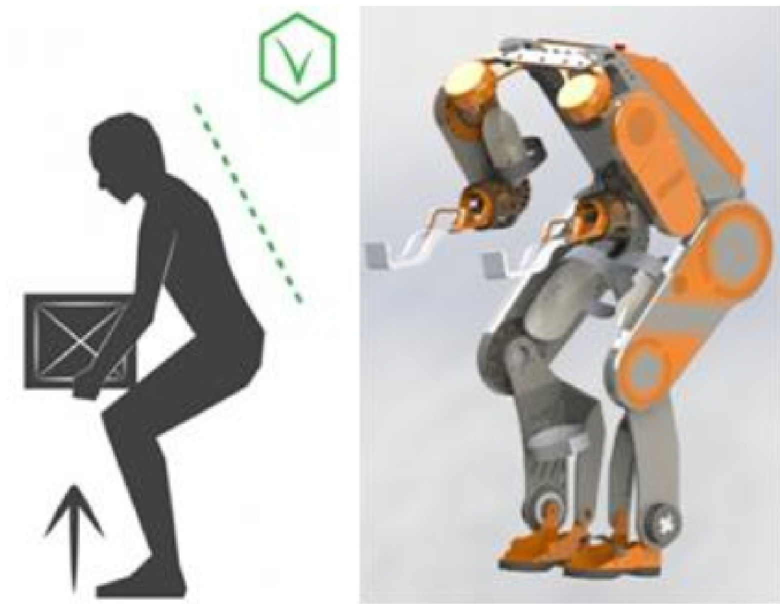

Fig. 44. Lifting posture of exoskeleton with a normal human lifting posture

Here , during the lifting scenario the hip joint will have maximum 40-45 dgree actuation & knee joitn will have 25-35 dgree actuation with respect to vertical . the intuated posture while lifting is shown in above figure

By considering the above posture in cad one can calculate required torque generated in this particular position if we know the CG of each components , its weight & distance of cg with respect to the joint considered .the below tale gives the mass of each components considered:

Table- XIII: Mass of major components and Sub-systems

Component	Mass(Kg)
Main Frame	9
Battery	38
Control systems	2
Cooling systems	0.6
Ergonomic pads	1.1
Bearings	0.7
Actuators	24
Cables & wiring	1
Safety systems	1.5
Miscellaneous	1.1
Total	**79**

Here we are only considering the CG & weight of actuator ,battery & Pay load of 300kg by neglecting other, the mass for specific actuators is given below.

Table- XIV: Mass of actuators

Motor	Joint	Mass(kg)
11040	Elbow, Shoulder Y	1.62kg
14540	Shoulder Z	2.9kg
17530	Knee	3.67kg
24040	Thigh-Hip	6.5 Kg

A) Hip-Joint:

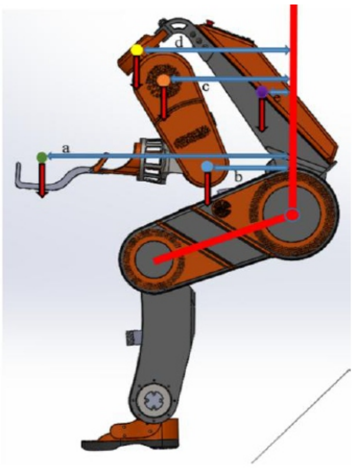

Fig.45 Illustartion of CG points W.r.t Hip joint

Here the exoskeleton components is CG is calculated, with respect to the hip joint, such the perpendicular distance is measured from the vertical red line to CG-points.. the payload considered was intended "300kg". The total length of the trunk was 54cm, the battery has weight of 38Kg & CG distance was calculated from the CAD model as below:

Table- XVI: CG OF Components W.r.t Knee-Joint

CG	Colour	Perpendic-ular Distance(m)	Force (N)=Mass x 9.8
Pay-Load	Grey	a = 0.32m	2940N
Elbow Motor	Blue	b = 0.14m	31.752N
ShoulderMotor (z-axis)	Orange	c = 0.02m	56.84N
ShoulderMotor (y-Axis)	Yellow	d = 0.05m	31.752N
Battery	Purple	e = 0.3m	372.4N
Hip Motor	Green	f = 0.33m	127N

Table- XV: CG OF Components W.r.t Hip-Joint

CG	Colour	Perpendicular Distance(m)	Force(N) = mass X 9.8
Pay-Load	Green	a=0.7m	2940N
Elbow-Joint	Blue	b=0.23m	31.752N
Shoulder-Joint-Z	Orange	c=0.36m	56.84N
Shoulder-Joint-Y	Yellow	d=0.42m	31.752N
Battery	Purple	e=0.08m	372.4N

From the above study & data acquired we can calculated Torque developed due to the weight Pay-load & actuators:

$$\tau = \underset{r}{\rightarrow} \times \underset{F}{\rightarrow}$$

$$\text{Total } \tau = [a \times F_1(payload)] + [b \times F_2(Elbow)] + [c \times F_3(Shoulder - z)] + [d \times F_4(Shoulder - y)] + [e \times F_5(Battery)]$$

$$= 2058 + 7.3 + 20.52 + 12.06 + 30 = \mathbf{2129Nm}$$

So, 2129Nm is the torque required while lifting a load of 300Kg, as 2129 is the total load, considering the loaded is divide in both leg on one individual leg the torque required will be 2129÷2=1065Nm in anti-clockwise direction

B) Knee-Joint:

In Similar manner to the hip joint the torque developed at the knee joint was also calculated, here for thigh joint with respect to the cad model dimension

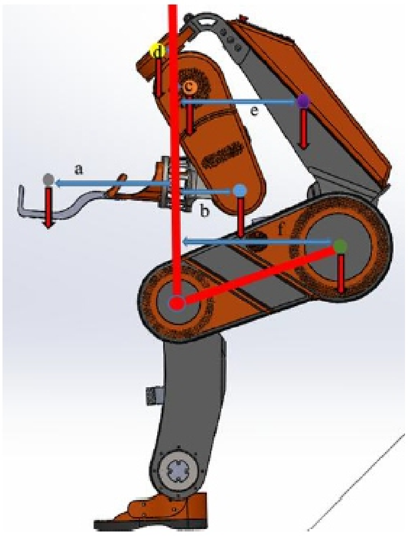

Fig.46. Illustartion of CG points W.r.t Knee joint

Similarly as before, total torque required is:

$$\tau = [a \times F_1(payload)] - [b \times F_2(Elbow)] - [c \times F_3(Shoulder - z)] + [d \times F_4(Shoulder - y)] - [e \times F_5(Battery)] - [f \times F_6(Hip)]$$

$$= 941 + (-)\ 4.4 + (-)\ 1.13 + 1.6 + (-)\ 111.7 + (-)\ 13.44 =$$

812Nm

Here, the torque is positive which means it is in anti-clockwise direction, the torque required was 812Nm, so for individual leg it will be 812 ÷2=406 Nm at each leg. 300 kg pay-load

2.)LocomotionCondition :

This condition can be evaluvated with the torque analysis Performed in Ansys-workbench , by the integration of normal gait values acquired from opensim simulation,

Note : the torque analysis in ansys was done by considering the payload as 300Kg & weight of exoskeleton as 60 , but here the exoskeleton weight is 79 , which is excess of 19 kg , which we can reduce from payload, so in actuall practice the exoskeleton can only carry 300 -19 = 281Kg of payload for the acquired normal reaction acquired through ansys The below Table Compares the torque Required in the above two conditions with the actual-torque available or generated by actuators

Table – XVII : Required Torque Vs generated Torque condition

Condition	Join t	Required Torque(Nm) per joint	Generated Torque-cont . (Nm) per joint
Static-Lifitng	Hip	1065Nm	1408Nm
	Knee	406Nm	744Nm
Continuous-Locomotio n	Hip	1378Nm	1408Nm
	Knee	808Nm	744Nm

It can be found from above analysis that while lifting the payload of 281 Kg& considering weight of exoskeleton as 79 kg as both the joints of Hip & Knee in each leg is working together the required torque is less is within the torque generated by exoskeleton , But in continuous locomotion we can see that Hip joint is well within out limits but for knee joint. that the required torque is more than the generated torque by the motor by a 8%, which implies that our designed actuator can only work under the 8% decreased payload of total 281Kg : which is:

[300-[[300×8]÷100]=258Kg.,

This ,is the max payload that the exoskeleton can operate

Maximum speed:
=Actuator on-load (rps) * ground to thigh height * No. of legs * Step arc length
=0.9 * 0.84 * 2 * 0.9
=1.36 m/s = 4.896 Kph

Battery life:
Considering the continuous operation of the suit with 80 kg for 45 minutes in 1 hour

Peak current*continuous current factor
=(89+118+147+353)*0.1=70.7 A
For every one-hour suit
will consume 53.02 Ah
Overall battery capacity is 190 Mah
On average 190/53.02 = 3.6 Hours.

The battery can last more depending on the speed of work and weight

XIII. RESULTS AND CONCLUSION

This paper introduces a the idea of developing a Full body exoskeleton suit prototype which is intented to be used for heavy duty application in Manufacturing sectors , Defence sectors & some civilian sectors .the design was fully mobile type & is not restricted to any particular space. the design was able to be validated in both static condition. static validation was done by manual computation & software compuatation "Ansys workbench" .Although Static structutral analysis was done the dynamic analysis was not performed due the limitation in hardware & Software tools , here dynamic analysis can be done in future which will further give us the result with more precision, here the end effector design was a simple "hook type"which is convenient for most of the uses ,but can be changed depending upon the payload characterstics

The user-actuator control was by the use of strainguage belts which was used around the limbs for the detection of signal for actuation . The gait Assist function Introduced in the prototype helps us in reducing actuation lag , this function also can be used as a reference limit for drive controll at which the device is actuated. The gait analysis was performed using an existing Opensimmodel , here further study & analysis of the gait cycle can be done for different conditions like in slope terrain ,steep terrain , rough terrain etc..from which the data could be used for gait assit function or for other computational needs.

The prototype was aimed to have a top speed of approximately 3 – 3.5m/s , the structural was designed to be able to survive the payload while locomoting under 3-3.5m/s , but due to actuators restrictedactuation speed the max speed is only around 1.36m/s . this is a the weight of the suit was expected to be under 60kg ,this was not able achieve ,the final weight is 79kg , the main components that contributed to increase in weight was actuator & battery. Battery capacity should be more inorder to be able to work continuously and at least 5% more power electronics systems would increase suits continuous performance.In future this drawback of actuators restricted power due to efficiency& weight of battery can be decreased , by further research for making the design more compact &ideal .

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Smart Blind Stick Design and Implementation

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ABSTRACT

Technologies are rapidly evolving, allowing people to live healthier and simpler lives. Sightless people are unable to carry out their everyday activities, such as walking down the street, visiting friends or relatives, or doing some other mundane tasks. As a result, the smart stick is a stick that can assist a person in walking safely without fear of colliding with another person or solid objects is proposed as a solution to this major issue. It is a development of the traditional blind stick as it acts as a companion for the blind when walking by sending audio alerts to the blind via a headphone connected to the phone with obstacles (water/walls/stairs / muddy ground) and also enables him to make a phone call to ask for help. Easy Edasoftware was used for designing and simulating electrical circuits, was used to model the electric circuit. This system functions similarly to a white cane in that it assists blind people in scanning their surroundings for obstacles or orientation marks. This system will be mounted on a white cane with an ultrasonic sensor, and a water sensor to detect changes in the environment. Ultrasonic sensors detect obstacles in front of it using ultrasonic wave reflection, water detection sensors detect whether there is a puddle.

Keywords: Blind Stick, SmartSystems, Embedded Systems. Android.

I. INTRODUCTION

Blindness is a state of lack of visual perception due to physiological or neurological factors. Imagine that you are walking in an unfamiliar place[1]. One has to ask for guidance to get to the destination. But what if the person is visually impaired. A person must completely depend on other people to get to the destination. In general, we note that the white cane is the best friend of visually impaired people. But oftentimes that stick isn't helpful. The Blind Stick is developed using many hardware and software applications. An individual with a disability is a member of society and has the same rights and responsibilities as people. But blind people face a large number of problems that are difficult to solve. Blind people are members of society, and their diversity in the world and social situations has been restricted. Blind people's disadvantages should not be seen as an excuse to shorten their lives; rather, they should be used as motivation to persevere. As a result, anyone with visual impairments requires assistance in the form of replacements for their eye function, specifically the visual function. In addition to the normal touch sticks, the blind often needs a switch for their sense of sight so that the ultrasonic and sound sensors can be used.

This smart stick will warn blind people about obstacles using the audio jack headphones, allowing the blind person to avoid an object in front of them[2]

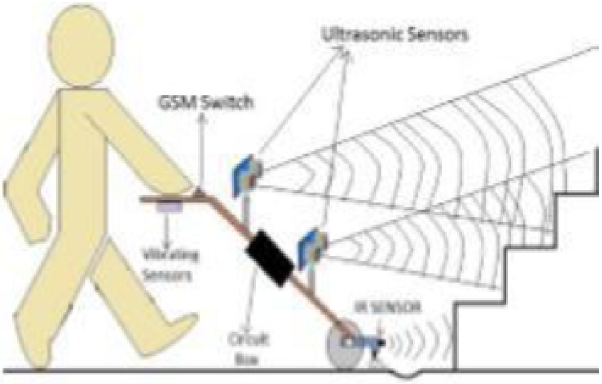

Fig.1. :Blind Man with Electronic Stick

II. PRINCIPLE OF OPERATION

The System Development Life Cycle (SDLC) is the process of developing and changing processes, as well as the models and methodologies used to construct an application and a software development process[3]. It involves the following steps:

A. Preparation: Needs evaluations, feasibility studies (both scientific and technological), and scheduling are also carried out as part of the planning phase.

B. Analysis : Direct observation is used during the research process to look at the problems that arise and are found in the materials, software, and hardware.

C. Design: At this point, the application will be explained in detail regarding the design phase of each component in the prototype under the needs addressed earlier in the prototype[4].

D. Implementation : The code is brought to life at this stage by selecting components and planning the software (coding/coding).

E. Testing : Testing is carried out at this point to see if the framework created satisfies the user's needs; if it does not, the next phase is iterative, i.e. returning to the previous stages. And the test is designed to identify and eliminate flaws in the device so that it can truly assist users in their everyday activities.

F. Maintenance : The system's operation starts at this stage, and minor repairs can be made if necessary.

III. PRIMARY OBJECTIVES

The main aim is to make new technology easier to use for visually disabled people. In a technology-controlled world where people strive to live independently, this work proposes an ultrasonic stick for blind people to aid them in achieving personal independence. It is simple to use due to its low cost and lack of bulk.

The ultrasonic sensor senses the presence of an obstruction and calculates the distance between the source and the target, a water sensor is used to detect the presence of water, and a fire sensor is used to detect the presence of fire by an alarm, vibration and sound.

Fig.2. Three Experimental Sticks

Based on the findings, it can be inferred that ultrasonic sensor sticks have proven to be extremely beneficial to blind people. This prototype has reduced the risk of blind people getting into accidents in difficult road structures with many obstacles, as well as when crossing the street. Since a large gap between the stick and the sensor can result in constant censorship of objects recognized around the stick, the design of the blind stick is made more flexible on the stick section, which is something to consider. The stick works by creating an Android-based mobile application that links the stick to the phone and performs a variety of tasks, including making phone calls to pre-determined numbers and determining the location. The stick is distinguished by its low price and simple nature. When the wireless sensor detects an object or obstacle in its environment, it serves as an input or input to the esp8266 processor. The audio jack connected to the headphone then emits sound. The lack of essential skills and preparation, as well as the limited range of motion and knowledge transmitted, are among the most serious shortcomings of these aids. Electronic assistive devices are intended to solve issues like these, and we used some electronics modules and sensors to adjust the cane. A buzzer, ultrasonic sensors, and a water sensor are all included. The blind person walking with an electronic stick. Two ultrasonic sensors are mounted on the stick having a set to different ranges for avoiding small obstacles. Three push buttons that can be operated with the thumballows the blind user to send a general message (I am in trouble, help me) on a saved mobile no, or make a call for help. Vibrating sensors along with a buzzer used for beep and vibration if the stick is about to hit any obstacle. The circuit box containsa combination of microcontroller circuitry. The co-operation between the Ultrasonic and others sensors are utilized to create a complementary system that can give reliable distance measurement. A schematic circuit is made to make it easier to make tools. The schematic consists of Esp8266, Battery, Ultrasonic Sensor, water sensor. The ultrasonic sensors in our proposed project are used to detect obstacles ahead using ultrasonic waves. When the sensor detects obstacles, it sends the information to the Esp8266. The Esp8266 then analyzes the information and determines if the obstacle is near enough. If the obstacle isn't near enough, the circuit has no impact. If the obstacle is approaching, the Esp8266 issues a voice warning. It also senses water and warns the blind by sounding. The vibrator is also included in the stick. If the obstacle is approaching, the Esp8266 vibrates to alert you. A water sensor is used to sense water.

V. SYSTEM DESCRIPTION

A. Ultrasonic Sensor It is an ultrasonic sensor, also known as an ultrasonic transducer, that is based on a transmitter and receiver and is primarily used to determine the distance from a target object with a wavelength ranging from 20kHz to 20 MHZ [5].

Ultrasonic sensors, like sonar detectors, work by transmitting a pulse of sound outside the range of human hearing. At the speed of sound (340 m/s), this pulse travels away from the range finder in a conical shape. The sound bounces off an object and is reflected in the range finder. This is interpreted as an echo by the sensor, which measures the time between transmitting the signal and receiving the echo. The object's distance is then calculated using this interval by a controller in simple notation[6]:

$$distance = \frac{elapsed\ time\ x\ speed\ of\ sound}{2}$$

The ultrasonic sensor is a robust and flexible sensing agent with relatively few limitations. Our ultrasonic sensors are in the air, non-contact object detection and ranging sensors that detect objects within an area. These sensors are not affected by the colour or other visual characteristics of the detected object. Ultrasonic sensors use high-frequency sound to detect and localize objects in a variety of environments. Ultrasonic sensors measure the time of flight for the sound that has been transmitted to and reflected from nearby objects. Based upon the time of flight, the sensor then outputs a range reading.

Fig3: Ultrasonic

B.NodeMCU ESP8266

The NodeMCU ESP8266 development board comes with the ESP-12E module containing the ESP8266 chip having TensilicaXtensa 32-bit LX106 RISC microprocessor. This microprocessor supports RTOS and operates at 80MHz to 160 MHz adjustable clock frequency. NodeMCU has 128 KB RAM and 4MB of Flash memory to store data and programs. Its high processing power with in-built Wi-Fi / Bluetooth and Deep Sleep Operating features make it ideal for IoT projects[7]. The NodeMCU Development Board can be easily programmed with Arduino IDE since it is easy to use.

C. Water Sensor

Water sensor brick is designed to detect water and can be used to detect rainfall, water level, and even liquid leakage. An Electronic brick connector, a 1 M resistor, and many lines of bare conducting wires make up the majority of the brick[8]

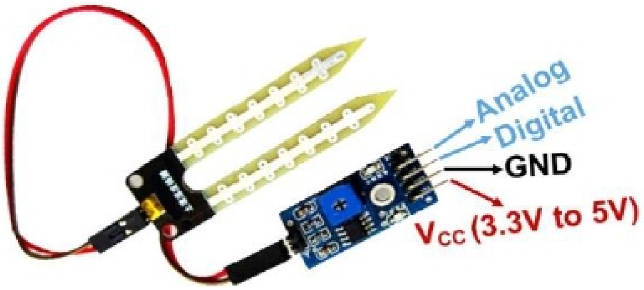

Fig.4.water sensor

VI. PROTOTYPE

The smart white cane is design as shown in fig 4,5 the stick uses ultrasonic sensors mounted on the stick sothat it will assist in carrying out daily activities, the water detector is placed at the front end of the stick which aims to detect whether theroad to be inundated by water or not and it connected to the speaker/buzzer.

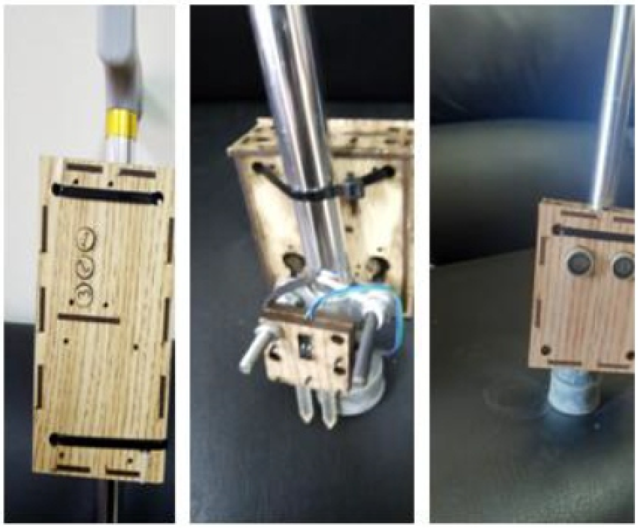

Fig.5.a.Three push boutton **Fig.5.b. Water Sensor** **Fig.5.a.Ultrasonic Box**

Fig.5. The final result

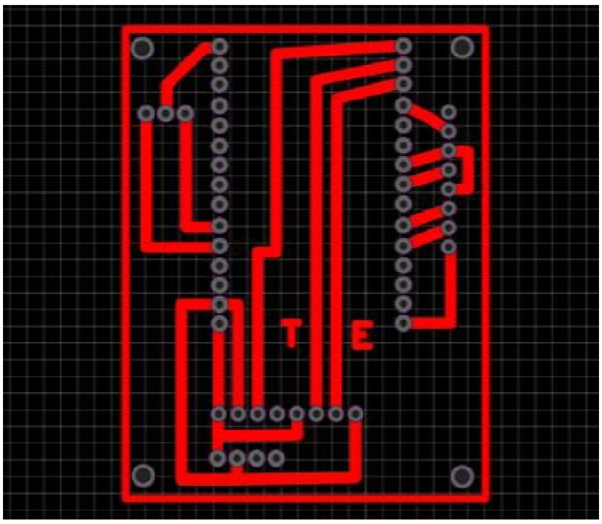

Fig.6. circuits by easy eda software

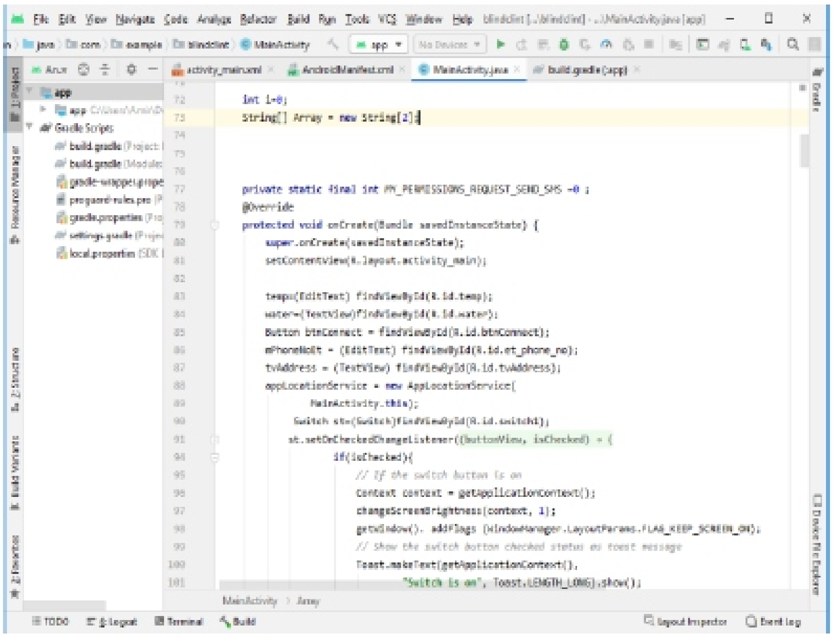

Fig.7. the shot screen of android code

Fig.8. the shot screen of Arduino ide

VII. ADVANTAGES& DISADVANTAGES

A. Advantages

1) Both indoor and outdoor navigation are possible with the device.
2) The location of a blind person may be monitored at any time, providing added security.
3) Detects obstacles and notifies the blind person through vibration and speech production.

B. Disadvantages

1) The battery must be charged.
2) If the stick is not charged, it will not work.

VIII. CONCLUSION

This paper has created a concept prototype of sticks for blind people that uses sensor technology to aid alertness and movement in the blind. The blind can sense objects up to 70 centimetres away and receive feedback in the form of sound and vibration. At this point, it's worth noting that the study's primary objective, which was to create and launch a smart walking stick for the blind, was fully achieved. The Smart Stick is a building block for the next generation of assistive technology that can help the visually impaired navigate both indoor and outdoor environments safely. It is both effective and powerful. Within a three-meter range, it performs well in detecting obstacles in the user's direction. With a noticeable short response time, this system provides a low-cost, dependable, lightweight, low-power, and robust navigation solution. Despite being hard-wired with sensors and other parts, the system is lightweight. Ultrasonic sensors with a large beam angle can detect a wide range of obstacles. In the future, further improvements will be made to enhance the system's efficiency. Both include a global positioning system (GPS) for determining the user's location and GSM modules for informing a parent or caretaker of the user's location. For ease of use, it should be able to handle a variety of grips.

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Forecasting Gold Prices in India using Time series and Deep Learning Algorithms

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ABSTRACT

The primary object of this paper is to compare the traditional time series models with deep learning algorithm. The ARIMA model is developed to forecast Indian Gold prices using daily data for the period 2016 to 2020 obtained from World Gold Council. We fitted the ARIMA (2,1,2) model which exhibited the least AIC values. In the meanwhile, MLP, CNN and LSTM models are also examined to forecast the gold prices in India. Mean absolute error, mean absolute percentage error and root mean squared errors used to evaluate the forecasting performance of the models. Hence, LSTM model superior than that of the other three models for forecasting the gold prices in India.

Keywords: Gold Prices, Box-Jenkins Methodology, ARIMA,Lag Variables, MLP, CNN and LSTMModels

I. INTRODUCTION

Gold is a precious metal and it is completely different from other assets and metals. It is highly liquid and sensitive to price changes (Ranson and Wainwright, 2005). A majority of gold is bought as jewelry items. In the gold consumption, India and China together account almost 60% of worldwide gold jewelry. Gold is consider as a traditional gift in many weddings and often given away on the occasion offestivals, such as Diwali, Akshaya Tritiya and Dantheras. Gold plays a unique role as a store of value and hedge risks (Taylor, 1998; Hammoudeh et al., 2010). People investing in gold have mainly two primary objectives, one being hedge against inflation as over a period of time (Baur and McDermott (2010) and Baur and Lucey (2010) and next is to mix your investment basket and hence diversify the risk and will help you reduce the overall volatility of your portfolio. Typically the return on gold investment is almost in line with the inflation rate. In modern days, people has to choose different ways to invest the gold by buying jewelleries which is safer way or by purchasing goldcoins and bars which is available in public sector banks nowadays or by investing in Gold Exchange traded fund (Gold ETF).Gold ETF is in financial instrument of mutual fund in nature which in turn invests in gold and these are listed in a stock index.
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Time series can be defined as a sequence of data points which is ordered in sequence and collected at regular time intervals. Time series approach can be used on any data which is changes over time. Time series are used in statistics, weather forecasting, sales forecasting, stock market predictions etc. In decisions, that involve factor of uncertainty of the future, time series models found one of the most effective methods of forecasting. The classical time series analysis procedure decomposes the time series data into four components: Trend, Seasonality, Cyclic and residual component.

There are a wide range of techniques to forecast the gold prices. There are classic econometric and statistical techniques like the exponential smoothing method (ESM), autoregressive moving averages(ARMA), auto regressive integrated moving averages (ARIMA) etc., Although these methods are useful to capture the linear relationship and they fail to capture the non-linear characteristics of gold prices. To tackle this problem, artificial intelligence (AI) models are implemented to forecast the gold prices. The common methods are Feed forward neural networks, Multilayer perceptron (MLP), Recurrent neural networks (RNN), Convolutional neural networks (CNN) and Long short term memory (LSTM).

II. MATERIALS AND MEHODS

The data collected from World Gold Council of gold prices in Rupees per gram, daily frequency ranging from January 2016 to December 2020 consisting a total of 1304 observations. The train and test data sets consists of 1277 and 27 respectively. We built the model on train dataset and predictions on test dataset.

Table 1: Average Daily Gold Prices (Rs/gram)

Average Daily Gold Prices (Rs/gram) in India				
Mon	Tue	Wed	Thu	Fri
2755.606	2756.874	2755.702	2756.907	2755.783

A. Review of Box and Jenkins Approach

The Box–Jenkins methodology is one of the well known method in the field of time series. This method applies ARIMA models to find the best fit of a time series to past values of this time series, in order to make accurate future forecasts. These methods are also commonly used when the data is not-stationarity.

Let $\{Z_t\}$ be the time series. Then $\{Z_t\}$ is stationary if E $(Z_t) = \mu$ and V $(Z_t) = \sigma_z^2$ for all t. Otherwise it is non –stationary Let $Z_1, Z_2 \ldots Z_N$ be an observed sample. If there is no trend line and constant variance for allvalues of t in the time series plot, then the time series is said to be stationary. Alternatively, if the ACF of sample diesout slowly is an indication for stationary.

The Box – Jenkins Methodology is valid for only stationary time series data. If the data is non – stationary, we convert it into stationary by stabilizing mean using successive differencing and stabilizing variance using logarithmic transformation. The Auto Regressive Integrated Moving Average model for the time series is denoted by ARIMA(p, d, q) and is defined by

$\varphi(B)\nabla^d Z_t = \theta(B)a_t$ where $\varphi(B) = 1 - \varphi_1 B - \varphi_2 B^2 - \cdots \varphi_P B^P$ is polynomial in B of order p and is known as Auto Regressive (AR) operator, $\theta(B) = 1 - \theta_1 B - \theta_2 B^2 - \cdots \theta_q B^q$ is a polynomial in B of order q and is known as Moving Average (MA), operator, $\nabla = 1 - B$, B is the Backward shift operator $B^k Z_t = Z_{t-k}$ and d is the number of differences required to arrive stationarity timeseries. AR(p), MA(q) and ARMA(p, q) may be obtained as particular case of it with parameter values (p,0, 0), (0, 0, q) and (p, 0, q) respectively.

The four steps procedure forBox-Jenkins method: Identification of model, Parameter estimation, diagnostic checking and finally model forecast.

B. Review on Deep Learning Algorithms

In the study of ANN, the most popular algorithm is a feed-forward neural network (FFNN). It has only forward connections in between the neurons. ANNS are commonly used for time series forecasting. ANNs can model any form of unknown relationship in the data with few assumptions. ANNmodels trained on train dataset and it can generalise on unseen data. Traditional time series are capable of modelling only liner relationships where as ANNs are capable of modelling any form of relationship in the data, especially non-linear relationships (Hornik et al., 1989). The forecasting accuracies are also better than other traditional time series models.

Tang et al. (1991) compared ARIMAmodel with deep learning model for forecasting and results show that deep learning models are better than the ARIMA. Claveria and Torra (2014) studied performance of ANNs and traditional time series ARIMA and finally showed that ANNs are higher accuratethan ARIMA model to a tourism-demand forecasting problem. Zhang & Kline (2007) paper revealed that the accuracy of the model is depends on the input variables, best network structure and also training procedure.

Multilayer Perceptron (MLP)

A multilayer perceptron (MLP)is a class of feed forwad artificial neural network(ANN). MLP Neural Networks can be formed a relation between the input and output data and it can be modelled by neural networks (Bildirici et al., 2010). It is an extension of feed forward neural network. A multilayer perceptron neural network with two hidden layers is depicted in Fig. 1 which consists of three types of layers—the first one input layer and output layer these two connected with hidden layers. In MLP, the input nodes are connected to the output nodes with the help of hidden layers in between the two layers. The input will be changed under the effect of the hidden layers, which behave in nonlinear way and the results of the changes multiply the weights will be transferred to the output nodes. Unlike to a feed forward network in a MLP the data flows in the forward direction from input to output layer. The number of neurons are trained with the back propagation learning algorithm. The major use cases of MLP are forecasting, recognition, prediction, pattern classification, and approximation.

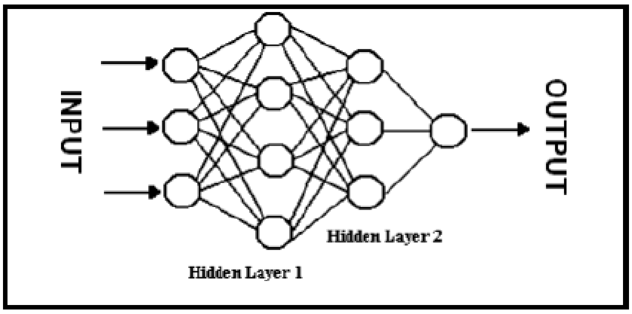

Figure 1. A simple schema of a three layer perceptron neural network

Fig. 1 representing a network structure of MLPwhere neural network has three inputs and two hidden layers with four and three nodes and one output node (3-4-3-1). A simple single layer perceptron is illustrated in the form of equation in Eq. (1).

$$o = f(\sum_{i=1}^{n} w_i \emptyset(x))(1)$$

In Eq. (1), the variable, x, is the input vector, $\emptyset$ is called the activation function and the output result of the MLP could be a number or a vector of zero numbers. The variable, w, is the weights and f is the output function. Log-sigmoid, ReLUand hyperbolic tangent are the different activation functions, which can be found in the neural networks literature. Activation function is the core of any node in the hidden layers of MLP changes the input of the node to the output. ReLUactivation function is used in this research which is presented in Eq. (2)

In deep learning models, the most commonly used activation function is Rectified Linear Unit. The function returns for any positive value x it returns that value back and 0 if it receives any negative input. It can be written as

$$f(x) = max(0, x)(2)$$

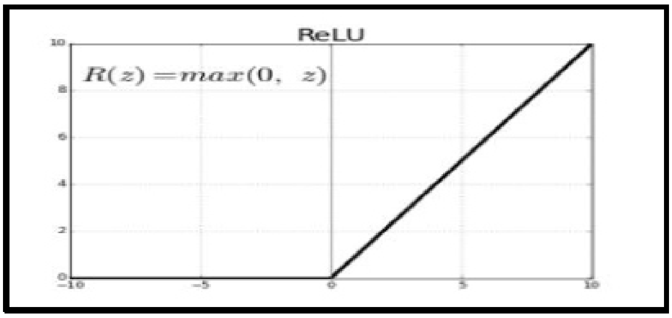

Figure 2. ReLU activation function

Long Short Term Memory (LSTM)

RNNs are a most powerful type of artificial neural network that can internally maintain memory of the input. In Recurent Neural networks(RNN) studies, one of the most common algorithm is LSTM.

The LSTM network is first developed by Hochreiter & Schmidhuber. Since RNN has maintain memory gate, this enables them particularly used for solving the time series problems.

One of the drawback of RNNs isto suffer from a problem called vanishing gradient which leads to the model learning becoming too slow or stopping altogether. LSTM models are developed such that To avoid the vanishing gradient problem. LSTMs have longer memories and can learn from inputs that are separated from each other by long time lags. An LSTM has three gates: an input gate which determines whether or not to let the new input in, an output gate which decides what information to output and finally the import gate which is a forget gate which deletes information that is not useful. These three gates are analog gates based on the sigmoid function which works on the range 0 to 1which is shown in Fig. 3 below.LSTM component is a end-to-end feature (enclosed in green dash box) with a three-layer model (consisted of input layer, LSTM unit layer and output layer).

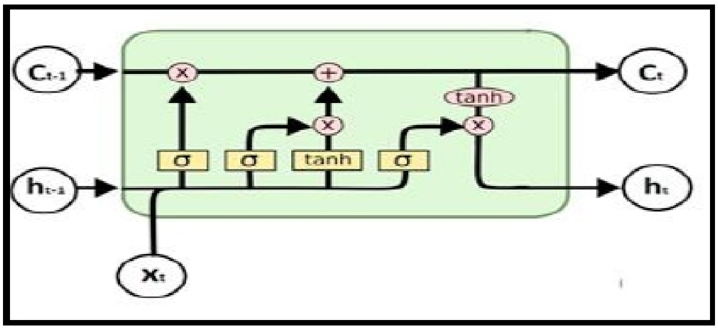

Figure 3. A simple LSTM Architect

Convolution Neural Networks (CNN)

In deep learning, a CNN is a class of Deep learning neural network, most commonly used for vision and image processing-based classification problems (object detection ,image classification, image segmentation, etc.). CNN are regularized versions of MLP. In MLP, each neuron in one layer connected with all then neurons of next layer. The ―full connectivity‖ of these networks make them prone overfitting of the data. Regularization is one way to deal the overfitting in the data. CNN take a different approach towards regularization.

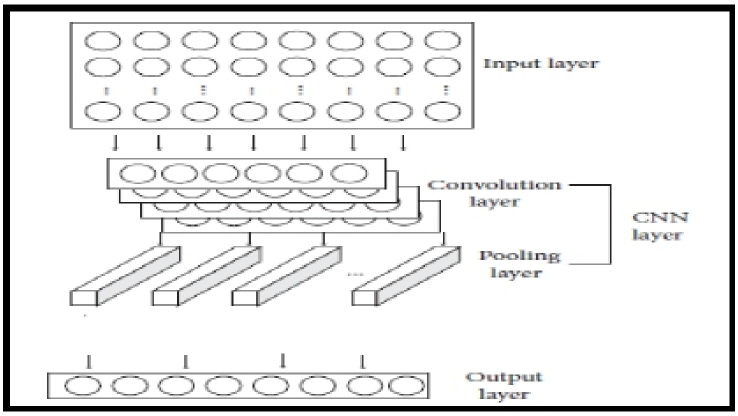

Fig 4. A simple CNN Architecture

The backpropagation process has been used to train the model in CNN model,The tuning parameters of the CNN:

- Number of hidden layers
- Number of neurons in each layer
- Learning rate
- Activation functions: ReLu, Sigmoid
- Epochs,

Batch size, Optimization algorithms: are SGD, ADAM and RMSProp

Measures:

If Z_t is the actual price for period t and $\widehat{z_t}$ is the forecast, then the error is defined as $e = Z_t - \widehat{z_t}$. The following measures may be considered

Root Mean Square Error (RMSE) = $\sqrt{\frac{1}{n}\sum_{t=1}^{n} e_t^2}$

Mean Absolute Percent Error (MAPE)= $\frac{1}{n}\sum_{t=1}^{n}\frac{|e_t|}{z_t} \times 100$

Mean Absolute Error (MAE) = $\frac{1}{n}\sum_{t=1}^{n}|e_t|$

III. ARIMA MODEL

Identification of Model To fit any traditional time series model, the initial step is to check the stationarity condition. Stationarity can be determined from a time series plot which should show constant mean and variance. It can also be checked from an ACF plot. Specifically, very slow decay in the lags in ACF plots indicates a non-stationarity.

Testing Stationary of Time Series

The stationary condition can also be determined by the testcalled Augmented Dickey Fuller (ADF) unit root test.

The hypothesis of the test are:

The null Hypothesis H0: Xt is non – Stationary and

Alternative hypothesis H1: Xt is Stationary

The p-value of the Augmented Dickey-Fuller (ADF) test equals0.996 and it is larger than the value of alpha= 0.05. This result indicates that the time series of daily Gold Prices in India is not stationary.

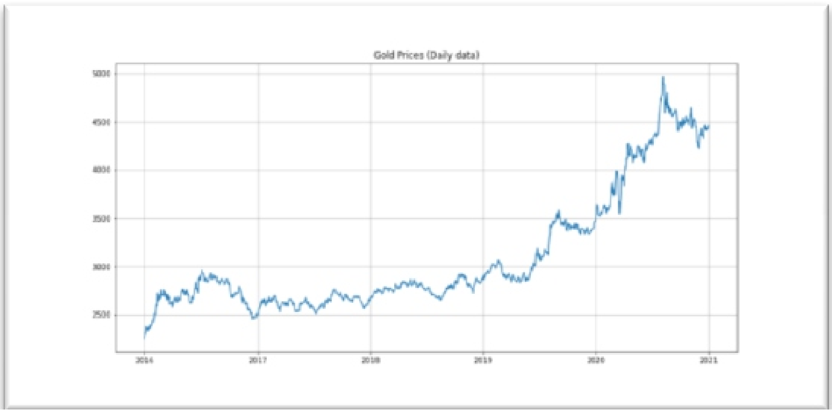

Figure 5: Time series plot of daily Gold Prices in India

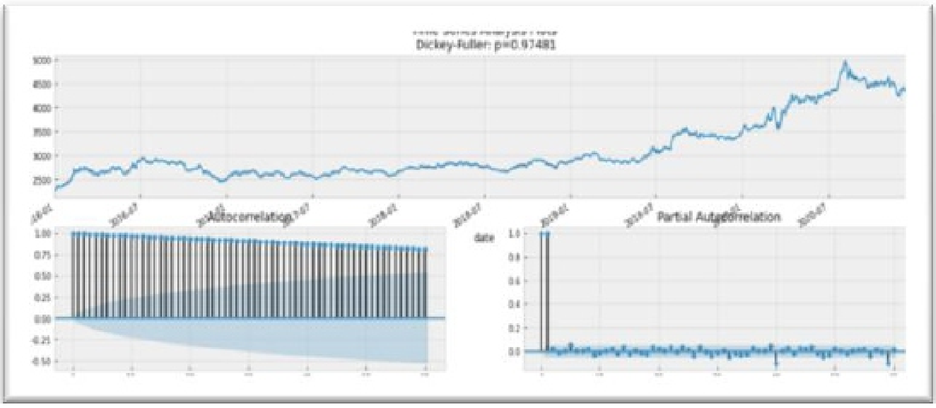

Figure 6: ACF and PACF for daily Gold Prices in India

All the above plots and results confirm that the original time series data is non stationary, and need to apply some transformations to convert it into the stationary series. The differencing method is used to convert non-stationarytime series into stationary time seriesof the data. In this paper, non seasonal difference of order 1 (i.e. d=1) is sufficient to achieve stationary in mean and variance. The derived variable . $W_t = \nabla^1 \hat{z}_t$ can now be examined for stationary.

Figure (7) displays the time series plot of the data after first differencing the series and indicates that the time series is a stationary series. To make sure of that, we conduct the unit roots test (Augmented Dickey-Fuller) for the transformed series Zt .

The p-value of the ADF test equals 0.00 which is less than the value of alpha=0.05 and this indicates that the non-stationary hypotheses of the differenced daily Gold Prices data is rejected and this demonstrates the success of difference transformation for the time series data of daily Gold Prices data. Thus, the series became stationary.

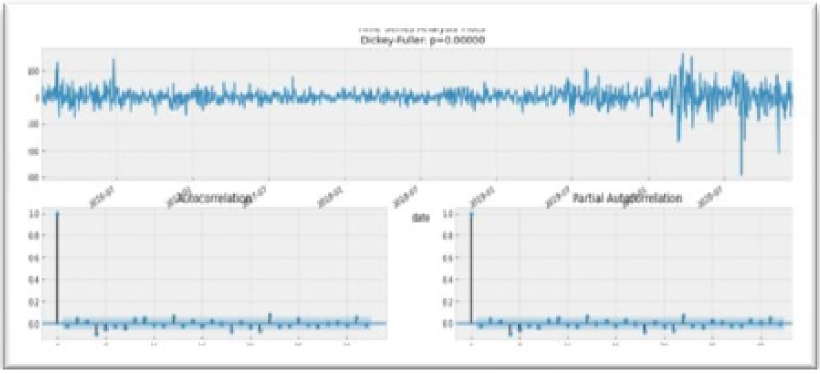

Figure 7: Time series plot,ACF and PACF of the first differences of daily Gold Prices in India of the first differences of Daily Gold Prices in India.

Model Identification

This section shows how we determine the optimum ARIMA model and identify the model specifications. We computed all relevant criteria by trial and error method to select the best ARIMA model for the data. ACF and PACFare used to determine the p and q values. The AR(P) model is taken from the PACF plot and MA(q) model is drawn from the PACF.

From figure (7), the ACF starts from p1 value, this means that the series may be Auto Regressive (AR) and as we can observe the ACF cuts off after lag (4).On the same lines, it can be seen that the PACF of the stationary series cuts off after time lag (4).

The following tentative models have been examined and estimated as shown in table (2) below. The best ARIMA model is chosen through the AIC criteria if it shows the lowest values of these criteria.

Table (2): Tentative ARIMA Models Criteria for the daily Gold Prices in India.

S.No	Parameters	AIC	S.No	Parameters	AIC	S.No	Parameters	AIC
1	(2, 1, 2)	12,359.2	6	(2, 2, 1)	12,370.9	11	(4, 2, 2)	12,374.3
2	(4, 2, 1)	12,361.7	7	(1, 2, 1)	12,371.2	12	(1, 1, 2)	12,374.8
3	(4, 1, 1)	12,364.5	8	(3, 2, 2)	12,372.5	13	(2, 2, 2)	12,374.9
4	(4, 1, 2)	12,366.4	9	(3, 2, 1)	12,372.8	14	(3, 1, 1)	12,375.0
5	(3, 1, 2)	12,368.1	10	(1, 2, 2)	12,373.0	15	(2, 1, 1)	12,375.4

It is shown in table (2) that the ARIMA (2, 1, 2)is significant with respect to parameters as well as adequacy of the model. This means that the ARIMA(2, 1, 2)model is superior among all the other models.

Parameters Estimation:

Dep. Variable:	**Price**
Model:	ARIMA (2, 1, 2)
Sample:	01-01-2016 - 24-11-2021
No. Observations:	1277
AIC	12359.2
BIC	12384.9
HQIC	12368.9

Table: 3 Model Parameters of the ARIMA (2, 1, 2) Model

	coef	std err	z	P>|z|	[0.025	0.975]
ar.L1	-0.5181	0.015	-33.997	0	-0.548	-0.488
ar.L2	-0.9352	0.019	-49.252	0	-0.972	-0.898
ma.L1	0.4994	0.012	41.209	0	0.476	0.523
ma.L2	0.9742	0.013	72.402	0	0.948	1.001
sigma2	935.98	16.118	58.069	0	904.38	967.57

The fitted ARIMA model for the daily gold price in India is

$$(1 + 0.52B + 0.93B^2)\ y_t = (1 - 0.50B - 0.97\ B^2)e_t$$

Diagnostic Tests:

The autocorrelations and partial auto correlations of the residuals plots are used for diagnostic checking.

Analysis of Residuals

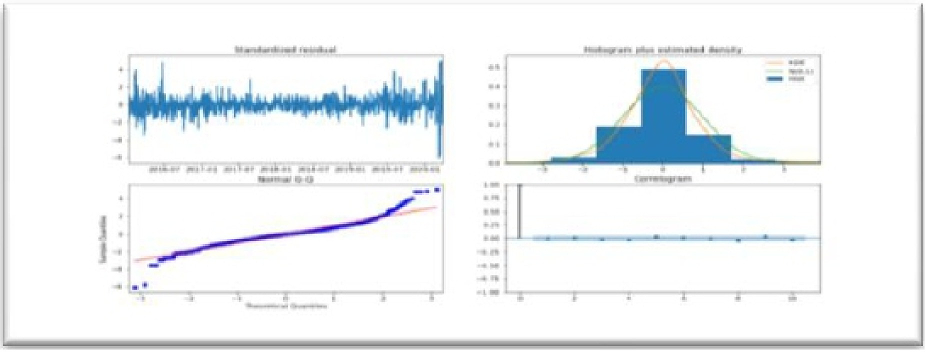

Figure (8): Residual Chart

Figure (8) show the estimated autocorrelation function for the residuals of theARIMA (2, 1, 2)model for the time series of daily Gold prices.

Box-Ljung Q- test statistic is used to test the adequacy of the model. The hypothesis on the model is below:

H0: The ARIMA (2,1,2) model is adequate.

H1: The model is ARIMA(2,1,2) inadequate.

Table (4): Ljung-Box Test Statistic

Ljung-Box (Q):	0.06		Jarque-Bera (JB):	7091.2
Prob(Q):	0.81		Prob(JB):	0
Heteroskedasticity (H):	3.21		Skew:	-0.67
Prob(H) (two-sided):	0.00		Kurtosis:	14.47

From the Table(4),the probability value of the test statistic is 0.81 which is greater than 0.05, therefore, we fails to reject Ho. Hence, we conclude that the ARIMA (2,1,2) model is an adequate model for the giventime series data.

IV. DEEP LEARNING MODELS

A. Multilayer Perceptron (MLP)

Python software has been used to train the MLP model on evaluate the model on test dataset. Structure of the Network: The MLP model consists of three: input layer, a hidden layer and an output layer. Two input neurons considered in this model, each representing the values of lag1 (previous day price in the same week i.e. lag1 gold price) and lag2 (lag 2 gold price). One output unit is needed in this modelwhich indicates the forecasts of daily gold price. Trial and error approach can be usedto find the optimal number of hidden units in the neural network. Typically we can use either the forward selection method or backward selectionto arrive the optimumthe hidden layer units. In the forward selection method, we choose a small number of hidden neurons then compute the network performance using RMSE, MAE and MAPE values. In the next step increment the hidden neuronsby one until train and test error is acceptably small or no further improvement is noted.

```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense (Dense)                (None, 500)               1500
_________________________________________________________________
dense_1 (Dense)              (None, 500)               250500
_________________________________________________________________
dense_2 (Dense)              (None, 1)                 501
=================================================================
Total params: 252,501
Trainable params: 252,501
Non-trainable params: 0
```

B. Long Short-Term Memory (LSTM)

Python software has been used to train the LSTM model on evaluate the model on test dataset.

Structure of the Network:

```
Model: "sequential_1"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
lstm (LSTM)                  (None, 1000)              4008000
_________________________________________________________________
dense_4 (Dense)              (None, 1)                 1001
=================================================================
Total params: 4,009,001
Trainable params: 4,009,001
Non-trainable params: 0
_________________________________________________________________
```

C. Convolutional neural networks (CNNs)

Python software has been used to train the CNN model on evaluate the model on test dataset.

Structure of the Network:

```
Model: "sequential_8"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv1d_6 (Conv1D)            (None, 1, 64)             192
_________________________________________________________________
flatten_5 (Flatten)          (None, 64)                0
_________________________________________________________________
dense_17 (Dense)             (None, 500)               32500
_________________________________________________________________
dense_18 (Dense)             (None, 1)                 501
=================================================================
Total params: 33,193
Trainable params: 33,193
Non-trainable params: 0
_________________________________________________________________
```

V. RESULTS AND DISCUSSION

The train dataset is used to train the models. Several traditional and deep learning models ARIMA, MLP, CNN and LSTM are examined. Once we trained the dataset using training dataset then we test the model on test dataset. The performance measures are showed in the Table5. Figures 9–12 represents the line charts of actual gold price and predicted gold prices.

Table 5: Accuracy measures for different models to predict daily gold price (Rs/gram) in India

Forecasting Model	Error Measures	Train Set	Test set
ARIMA	MAPE	0.7	2.19
	RMSE	70.1	110.55
	MAE	21.68	97.07
MLP	MAPE	0.69	0.72
	RMSE	33.28	38.85
	MAE	22.13	31.21
CNN	MAPE	0.71	0.74
	RMSE	33.95	39.93
	MAE	22.66	32.23
LSTM	MAPE	0.65	0.69
	RMSE	31.46	35.87
	MAE	20.59	29.31

The experimental results revealed that the LSTM model is the best among the four methods. In terms of forecasting performance measures, MAPE is 0.69, MAE is 29.31 and RMSE is 35.87, which is the lowest among the four forecasting models. Therefore, the LSTM model is superior to the other three comparative models in terms of forecasting gold prices in India.

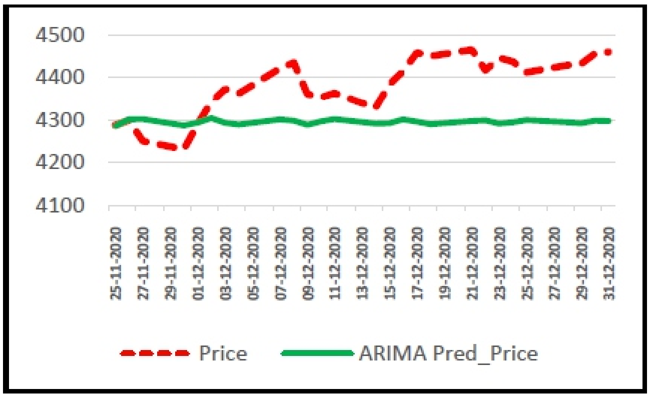

Figure. 9: ARIMA prediction (forecasted) of gold price(Rs/gram).

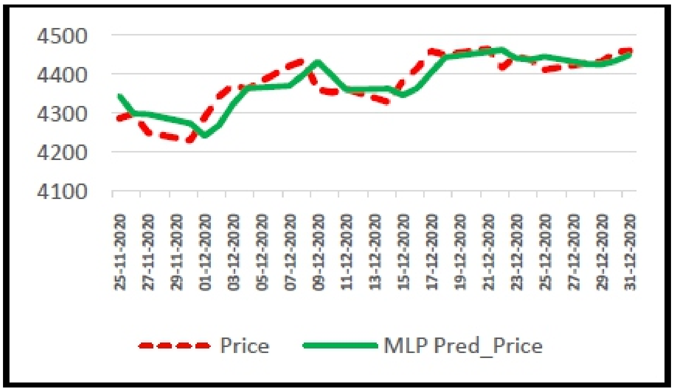

Figure. 10: MLP prediction (forecasted) of gold price(Rs/gram).

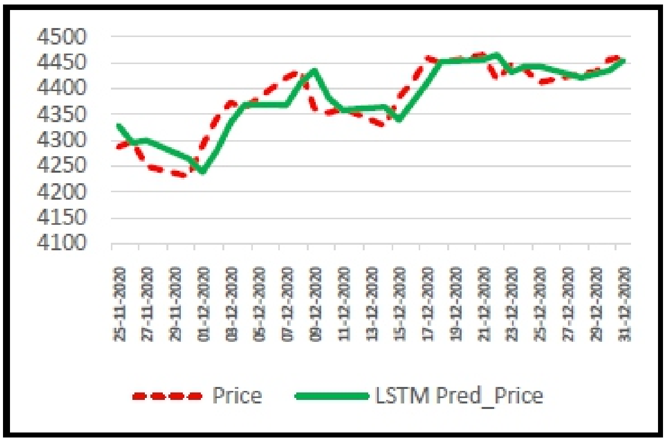

Figure 11: LSTM prediction (forecasted) of gold price(Rs/gram).

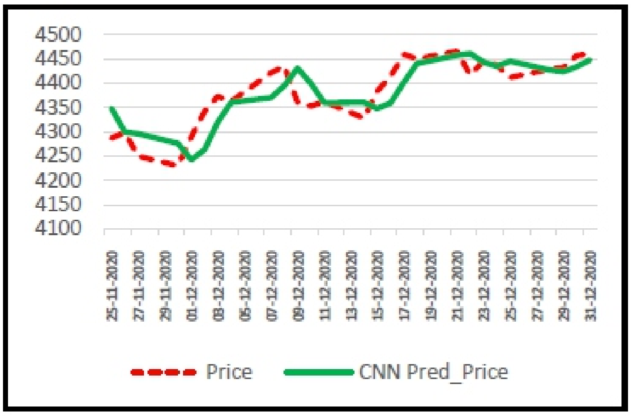

Figure. 12: CNN prediction (forecasted) of gold price(Rs/gram).

VI. CONCLUSIONS

The main object of the paper is to compare the traditional time series models with deep learning algorithm. The historical data is collected from World Gold Council of gold prices in Rupees per gram, daily frequency ranging from January 2016 to December 2020. LSTM model out forms than other three models to forecast the gold price in India using historical data. This study is based on secondary data collected from. The analysis showed that the LSTM model has the lowest MAPE, RMSE and MAE and performed better compared with the traditional time series model like ARIMA, MLP and CNN. However, the model can be improved further by incorporate other factors such as US dollar, Crude oil, Inflation and Bank rates into the forecast model. Our future research work is mainly to incorporate some explanatory variables which are influences the gold prices to ensure the accuracy of gold forecast. Forecasts for test data using LSTM model presented in the following table (6).

Table 6. Gold price forecasts using LSTM model for the test dataset

Forecasting Model	Error Measures	Train Set	Test set
ARIMA	MAPE	0.7	2.19
	RMSE	70.1	110.55
	MAE	21.68	97.07
MLP	MAPE	0.69	0.72
	RMSE	33.28	38.85
	MAE	22.13	31.21
CNN	MAPE	0.71	0.74
	RMSE	33.95	39.93
	MAE	22.66	32.23
LSTM	MAPE	0.65	0.69
	RMSE	31.46	35.87
	MAE	20.59	29.31

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Development of QGIS Plugin to Monitor the Health Condition of a Lake

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A B S T R A C T

Monitoring the quality of surface water is an important step towards sustainability of water resources. Quantum Geographic Information System(QGIS) is an open-source desktop application which is used for editing and analysing geospatial data. This study aims to develop a QGIS plugin named Lake Ecosystem Tool to monitor the health condition of a lake in terms of water quality index, trophic state index, hazard quotient, aerial water spread and volumetric change and the same can be used as a planning tool for the sustainable management of existing water bodies.

Keywords: Health condition, Lake, Lake Ecosystem Tool, plugin, Quantum Geographic Information System.

I. INTRODUCTION

Water is valued as one of the most valued resource for the survival of all living things. Hence preserving and if possible rejuvenating the existing water environment is very much essential for life sustenance. Of late, the decline in water quality due to infusion of multitudinous pollutants into the natural water bodies is an issue of global concern. Monitoring health condition of lakes is thus anessential step in making appropriate decisions in the right direction for improving the existing water quality. The need of the hour is quality monitoring and restoration of existing natural water systems [17]
.

Freshwater makes up only 2.5percentage of all the water available on this planet, out of which less than 1 percentage is directly available for human consumption. It is estimated that one sixth of the global populace are living in areas where they don't have access to safe drinking water as a result of unsustainable water consumption, population explosion, industrialisation and climate change[16]. Moreover, the quality of the available water resources is also questionable due to overwhelming pollution. This calls for the adoption of efficient conservation measures for protecting the existing freshwater bodies.

Nowadays Geographical Information System (GIS) and Remote Sensing (RS)applications work hand in hand to survey large water spread areas, to compute water quality by sensing parameters namely pH, chlorophyll concentration, turbidity and salinity, and is considered as one of the most powerful tool to solve complex research problems in theconservation and management of natural habitats. With recent advances in space technologies, multi-spectral satellite images provide satisfactory spectral resolution which can be used to determine the landuse landcover changeswith less error[14].

QGIS (QuantumGeographical Information System) is an open-source desktop GIS application which supports data formats for both tabular and spatial information[2].QGIS can read both raster and vector files and the software can georeference images as well[1].

The QGIS core is developed using toolkit and C++ and Plugins written in C++ or Python enhances the capabilities of QGIS that helps to add extra features to the existing GIS software. Independent developers has extended the core functionality of GIS using python plugins as well[4].

Qt Creator is an integrated software development environment that supports designer tools for developing Qt GUI (Graphical User Interphase) which is part of the SDK (Software Development Kit)[3]. Qt Creator includes a code editor and integrates Qt designer for designing and building graphical user interfaces (GUIs) from Qt widgets[5].In this study Qt Creator is used as a tool to create the framework of plugin which is used to monitor the health condition of a lake.

In order to monitor the health condition of a lake in terms of different parameters, a common platform can be provided in the form of a QGIS plugin. The objective of this paper is to develop a plugin in QGIS named Lake Ecosystem Too lto monitor the health condition of a lake. It includes selected parameters related to water quality, water spread area, and volume of the lake.

Tool namely Ecosystem Health Index (EHI) was developed by Xuato assess the water quality of a series of Italian lakesona scale ranging from 0 to 100 where 0 denotes the worst water quality and 100 the best water quality[20].Carlson developed an index namely Trophic State Index (TSI) to indicate the eutrophication condition of lakes in a scale ranging from0 to 100 and the same was calculated using parameters namelysecchidepth, nitrogen content, phosphorus concentration and chlorophyll-a. [6].

Swamee and Tyagi expressed water quality with the help of an aggregate index which consisted of subindices. The same was done to reduce the problems of rigidity, eclipsing and ambiguity with respect to the number of water quality variables required to be aggregated in a given index[15].

Peterson, carried out a study on determining the primary productivity of an aquatic environment and used the 14C-C02 method to describe the carbon flow in planktonic ecosystems [18].

Arias-Gonza´lezet al.,used extensive ecological data of Chinchorro Bank Biosphere Reserve to assess the rich biodiversity in coral reefs applying GIS and RS tools and predicted the same in terms of coral reef fish diversity index and habitat classification [8].

Carpenter et al., detailed on the lake primary productivity and demonstrated that the top to bottom control of primary production by nonliving components and a trophic cascade involving predation offish[9].Dodson et al., discussed about the relationship in lake communities between the rate at which solar energy is converted to organic substances and the number of species present in that community and concluded that the same strongly dependent on water spread area of the lake [10].French developed a simple procedure to determine the Hierarchial Richness Index which could be applied at any level of top to bottom ecological heirarchial system[11].Theresearch carried out by Goldman detailed on the role ofprimary productivity, nutrients, and transparency in cultural eutrophication[12].Lawhead discussed the creation of plugins using Python programming in QGIS[5].

II. METHODOLOGY

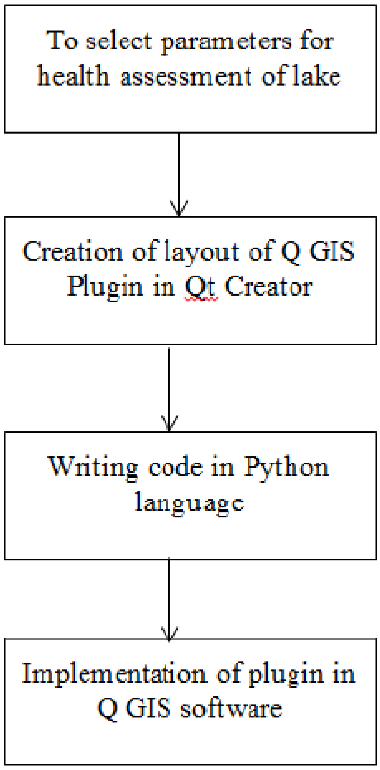

Fig. 1.Flow chart representing the methodology for creating QGIS plugin

The flow chart representing the methodology for creating QGIS plugin is shown in Fig.1.Different parameters selected in this study for the creation of QGIS plugin to determine the health condition of a lake areeutrophication in terms of Trophic State Index (TSI), water quality parameters in terms of Water Quality Index (WQI), heavy metal contamination in terms of Hazard Quotient (HQ), areal change in the lake water spread and the volumetric change of the lake. The different indices used in this study are discussed as follows.

HQ is expressed as the ratio of exposure contaminant concentration and the reference contaminant concentration and the same is used to determine the health risk. Values of HQ less than or equal to 1 indicates that ill effects are least expected. If the value of HQ is greater than 1, it does not mean that adverse effects will occur, but the same warrants a thorough analysis on the sampling locations where the concentration of chemicals has exceeded.

WQI derived from physical, chemical and biological parameters are expressed in terms of a single value and the same represents the overall water quality of the water body with respect to space and time. The said index simplifies a complex data set that is easily understandable by the public and sustainable conservation measures can be adopted by the policy makers as well [19].

National Sanitation Foundation Water Quality Index (NSFWQI) is commonly used for assessing water quality and the same has served as the basis for several other water quality indices that was developed later.The one developed by Swamee and Tyagiis commonly used to determine the water quality in Southern part of India and the same is mathematically expressed as (1).

$$I = \left(1 - N + \sum_{i=1}^{N} S_i^{-1/k}\right)^{-k} \quad (1)$$

Where,

N=Number of parameters chosen

S =Subindex value for ith water quality variable

k =0.40

The value of WQI developed by Swamee and Tyagi ranges from 0 to 1 and the description for each division is given in table 1.

Table- 1: Range of Water Quality Index developed by Swamee and Tyagi

WQI range	Qualitative descriptor of WQI
0–0.25	Poor water quality
0.26–0.5	Fair water quality
0.51–0.7	Medium or average water quality
0.71–0.9	Good water quality
0.91–1.0	Excellent water quality

Limiting nutrients namely nitrogen content and phosphorus concentration, along with water transparency and chlorophyll-a concentration is used for calculatingTSI[13],[7].Carlson's TSI is commonly used to determine the trophic condition of water bodies and the same is defined as the total weight of organic content at the time of measurement. The mathematical expression developed by Carlson is given as (2) [6].

$$TSI = 0.25\ (TSI_{SD} + TSI_{Chl\text{-}a} + TSI_{TP} + TSI_{TN}) \quad (2)$$

Where $TSI_{SD} = 60.0 - (14.41) * \ln(SD)$

$$TSI_{TP} = (14.42) * \ln(TP) + 4.15$$

$$TSI_{TN} = 54.45 + (14.43) * \ln(TN)$$

$$TSI_{Chl\text{-}a} = 30.6 + (9.81) * \ln(Chl\text{-}a)$$

Where SD = Secchi Depth (m),TP = Total Phosphorous(µg/L),TN = Total Nitrogen (µg/L) and Chl-a = Chlorophyll (µg/L). A lake is classified based on the TSI value and the descriptor words for the corresponding trophic classes are given in table 2 [6].

Table-2: Classification of lakes based on TSI

TSI	Lake Classification
<40	Oligotrophic
40-50	Mesotrophic
51-70	Eutrophic
>70	Hypereutrophic

III.RESULTS & DISCUSSIONS

The creation of plugin is carried out using the plugin builder plugin, which is accompanied with QGIS software. By installing the specific plugin, it leads the way to create a new plugin according to one's needs. The required inputs namely class name, plugin name, etc. should be given properly and the description for the new plugin is also given. Module name is also given to save the plugin. The details of author and the way they appear in the menu bar are shown in Fig. 2 and the plugin builder output is shown in Fig.3 respectively.

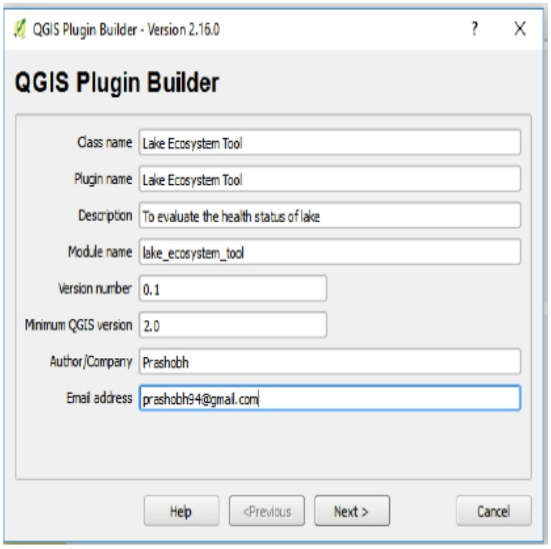

Fig. 2.Plugin creation using plugin builder tool in QGIS

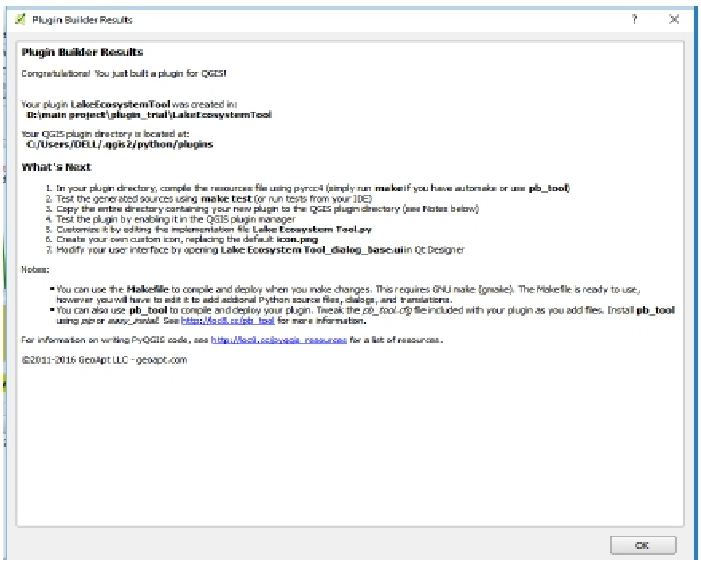

Fig. 3.Plugin builder output

After successful creation of plugin, the saved plugin should be called into the QGIS software. For this purpose, OSGeo4W(binary distribution of a broad set of open source geospatial software for Windows environment) shell is attached to QGIS software, which act as a binding of Python language to QGIS software. By opening, OSGeo4W shell, a window which is shown in Fig.4 is displayedwhichwill provide a space to give commands to get necessary outputs. Here, 'make' command is used to call the saved plugin into the QGISenvironment.

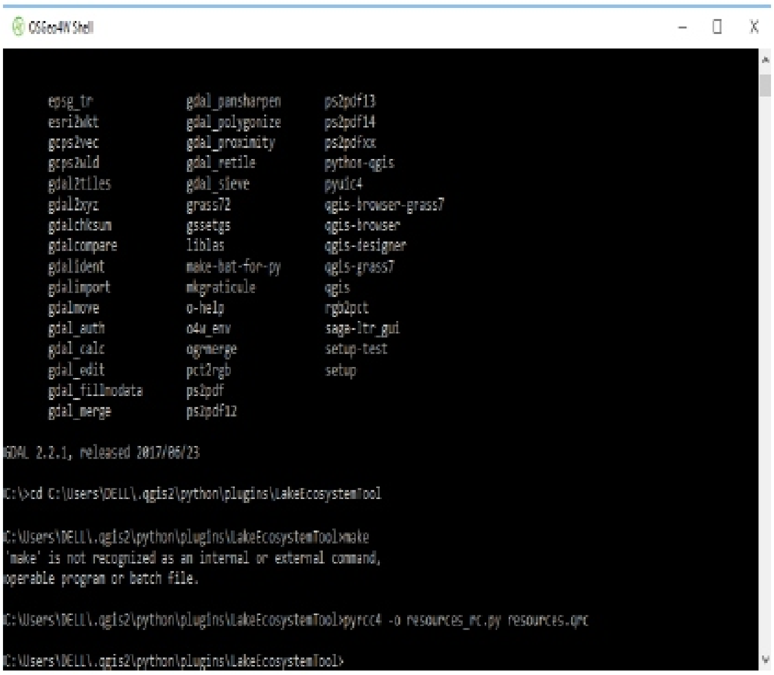

Fig. 4.Calling of plugin to the QGIS environment

After successful calling, the QGIS software can be opened to see whether the plugin is successfully created or not. The successfully created plugin here is saved as an experimental plugin named "Lake Ecosystem Tool" and the same is shown in Fig.5. Detailed description are also shown inFig.5 including the location of saved plugin in the system. Manual uninstalling and reinstalling of plugin can be done in QGIS, without using the code language.

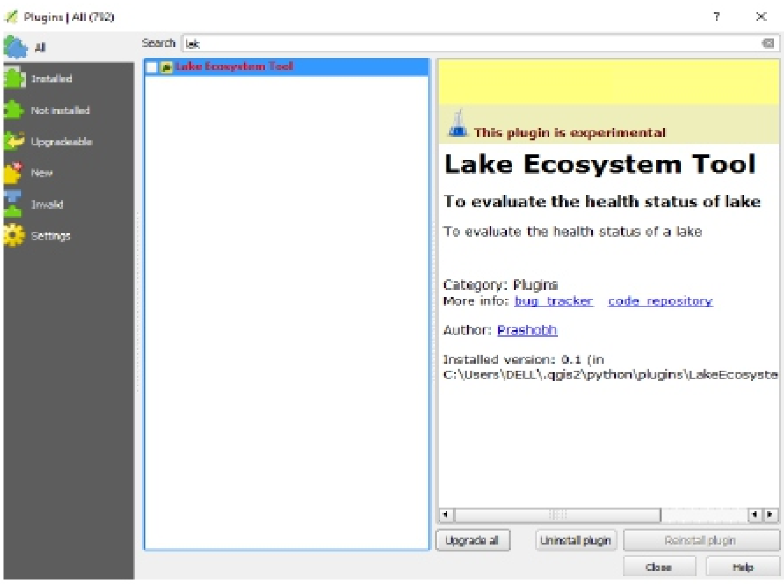

Fig. 5.Addition of QGIS plugin to the QGIS environment

The next step was to create the user interface of the plugin using the binding software, QtCreator and the same is shown in Fig.6.Qt Creator organisesits source code in projects and the researcher can configure QtCreator for compiling and editing one's code.

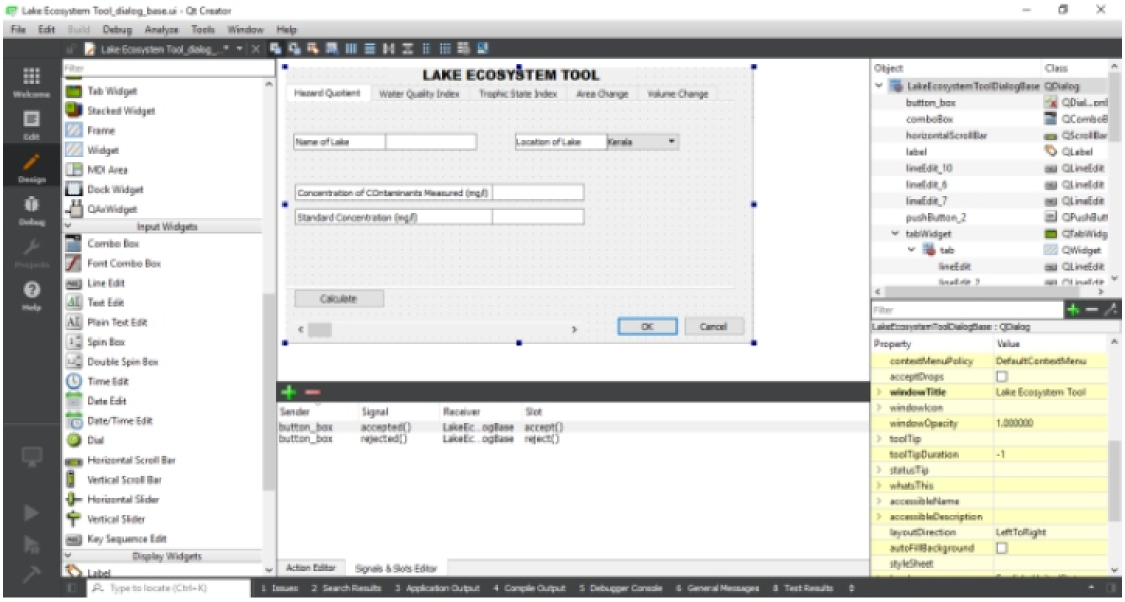

Fig. 6.Creation of user interface of plugin using QtCreator

The layout of the Lake Ecosystem Tool developed to calculate different indices such as HQ, WQI, and TSI are shown in Fig.7, Fig.8, and Fig.9 respectively. The same also provide the tabs for computingthe areal change and volume change of the lake. Provision for providing the name and location of lake is also given. Parameters can be selected from the scroll menu and the respective one can be given as input with proper units.Indices namelyHQ, WQI, and TSIcan be calculated using the relevantequationsand the same can be selected from the scroll menu.

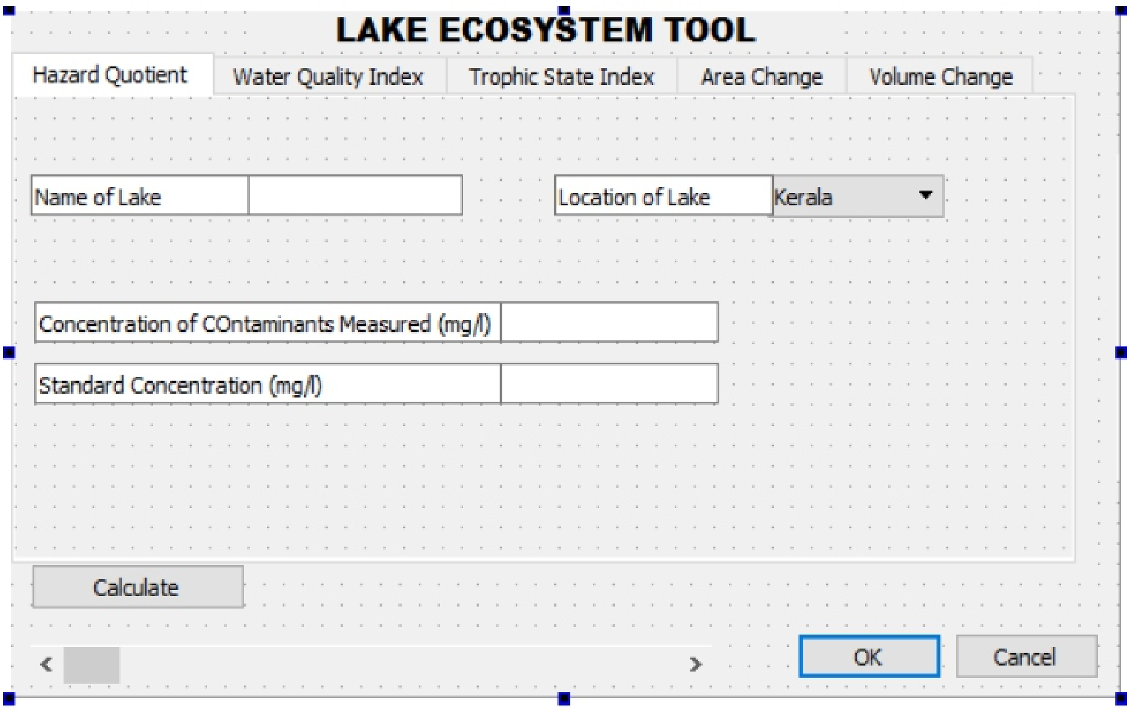

Fig. 7.Layout of plugin : Hazard Quotient tab

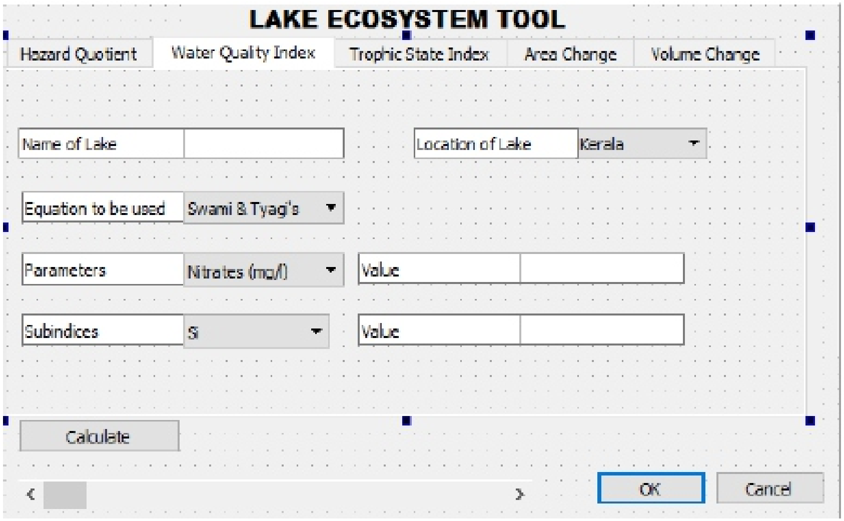

Fig. 8.Layout of plugin : Water Quality Index tab

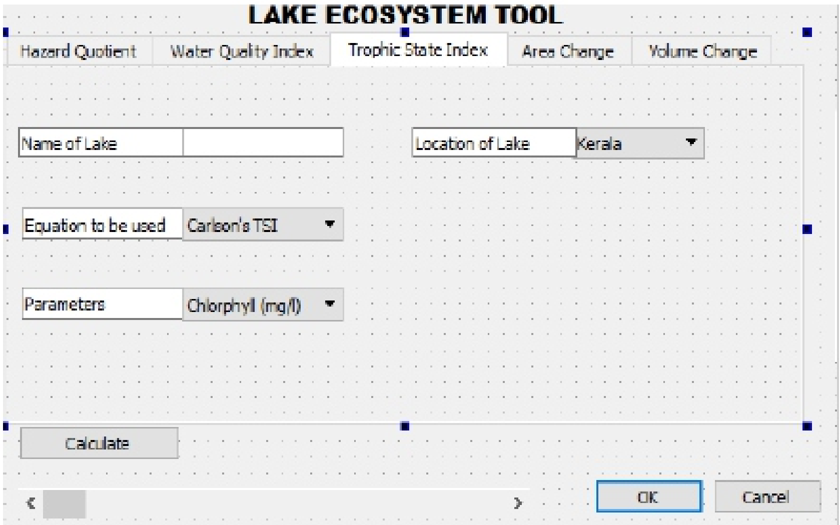

Fig. 9.Layout of plugin :Trophic State Index tab

Thereafter the Python code was edited within this software to provide the logic to the given layout. After successful edition of python language, the same provides the logical outputs expected as per one's requirement. Fig.10 shows thepython binding in QtCreator to provide the logic in the preferred manner.

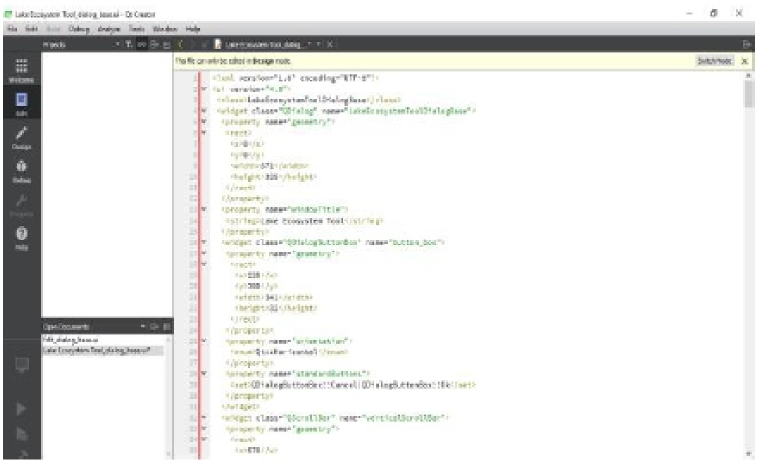

Fig. 10.Python code to bind the created plugin for the preferred logic

IV. CONCLUSION

Lake Ecosystem Tool developed in this study could be used a simple valuable tool for assessing the health condition of lakes and the same can also be used for comparing the health status of a series of lakes.

ACKNOWLEDGMENT

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Dielectric Elastomer Grippers

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A B S T R A C T

This paper appraisals state-of-the-art dielectric elastomer actuators (DEAs) and their forthcomingstandpoints as soft actuators which have freshly been considered as a crucial power generation module for soft robots. DEs behave as yielding capacitors, expanding in area and attenuation in thickness when a voltage is applied. The paper initiates with the explanation of working principle of dielectric elastomer grippers. Here the operation of DEAs include both physics and mechanical properties with its characteristics, we have describe methods for modelling and its introductory application. In inclusion, the artificial muscle based on DEA concept is also formally presented. This paper also elaborates DEAs popular application such as- Soft Robotics, Robotics grippers and artificial muscles.

Keyword : Dielectric Elastomer, Soft Grippers, Principle, Artificial Muscle, Soft Robotics, Electroactive Polymer, Voltage, Current

I. INTRODUCTION

From past few years, an encroachment is seen in robotics, where rigid conventional robots are transcending to soft robotics with compliant structures, in this area electroactive polymers have been proposed as one of the benefactor, which is resulted in implementing it as flexible actuation mechanism. Electroactive polymer, as a classification of polymeric material that deform under electrical impulse, are appearing as auspicious replacement of current used materials for actuation and sensing application. In conflict to traditional actuator material (e.g. piezoelectric ceramics) which are better for lifting high capacity load, but small deformation, comparatively electroactive polymer are featured by their gentleness touch, flexibility, and the consequent large- deformation. Their properties resemble as artificial muscle and expected to provide soft grippers for industries and attracts attention of various robotics firm.

A simple design of DE film is shown in Fig 1. Here pair of electrode are attached to both side of film, after which electric field is transmitted through the thickness of film. The electrode used before was rigid, but in present condition it can be stretchable, which will help in gaining large area of deformation.

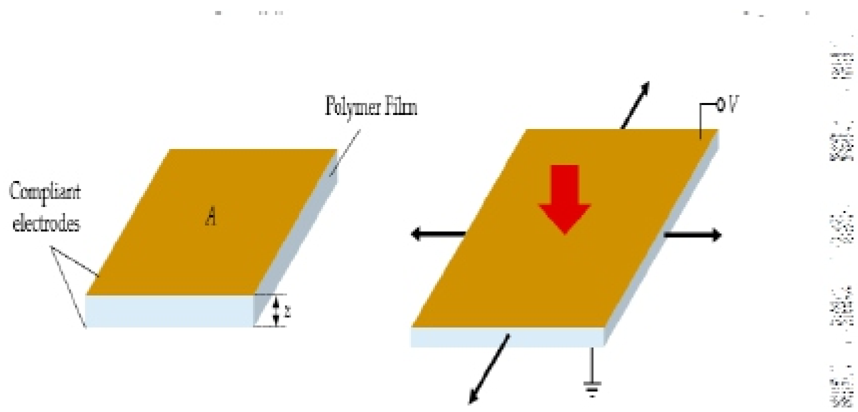

Fig1. It shows the DE operating principle, according to the voltage on/off.

In this paper, we have experimented a method to create soft grippers based on electrostatic actuation with intrinsic electro-adhesion force, which allow to control deformable, delicate objects of any dimension with controlled signal. We legitimize the method with two finger grippers as shown in figure 2.

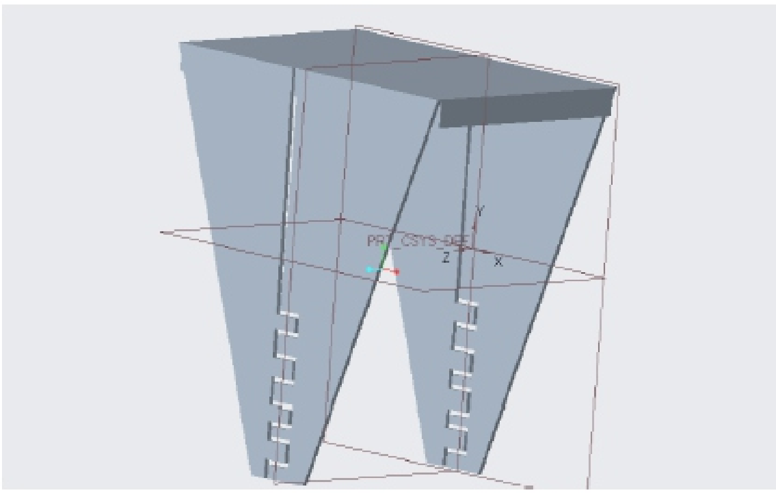

Fig 2. It shows modelling of gripper used through mechanism

It is roughly weighing around 1.8 g, which can carry upto 400 times its weight. For instance, fragile object like egg (63 g) and comparatively a can of about (500g). Further between both the grippers a line that divides into two part is for separating positive and negative terminal. Here the gripper will be of carbon conductive paint, which will be easy to contract and relax while applying voltage to the gripper. Due to this paint a transmission of current through the acrylic polymer sheet will be uninform throughout the gripper.

This paper emphases on the review of conjectural competencies and upcoming lookout of Dielectric elastomer actuators for robotics application. This review explicates the answer of subsequent question like, why do we need indulgent robotics grippers?[6],manipulative and modelling of DE material[7], Define countless parameters at which interruption of acrylic polymer sheet (EAP) befalls.[8]

II. RESULTS

[6]Augmentations in soft robotics, materials science, and stretchable electronics have empowered precipitous progress in soft grippers. Compared to rigid grippers, end-effectors fabricated from flexible and soft components can often grasp or manipulate a larger variety of objects. Such grippers are an

example of morphological computation, where control complexity is greatly reduced by material softness and mechanical compliance. Advanced materials and soft components, in particular silicone elastomers, shape memory materials, and active polymers and gels, are increasingly investigated for the design of lighter, simpler, and more universal grippers, using the inherent functionality of the materials. Embedding stretchable distributed sensors in or on soft grippers greatly enhances the ways in which the grippers interact with objects. Challenges for soft grippers include miniaturization, robustness, speed, integration of sensing, and control. Improved materials, processing methods, and sensing play an important role in future research.

[7]The actuation of DEs can be approximated as the lateral electrostatic compression and planar expansion of an incompressible linearly elastic material where the electrical component is treated as a parallel plate capacitor. The incompressibility constraint can be expressed as

$$Az = P$$

Where A is the area of the electrodes, z is the thickness of the elastomer film between electrodes, and P is a constant. The stored electrical energy on the DE is given by the stored energy on a parallel plate capacitor.

[8] We conducted several experiments with and without carbon paint with various materials and dimensions to test breakdown.

SR.NO	Material	Dimensions	Breakdown Voltage KV	Breakdown Ampere DC/AC
1)	Acrylic Sheet	5” x 4”	14 KV	12 mA
2)	Acrylic Sheet with Carbon paint	5” x 4”	11KV	12 mA
3)	VHB 4910	4” x 2”	7KV	17 mA
4)	VHB 4910 with Carbon Paint	4” x 2”	5KV	19 mA
5)	Piezoelectric Ceramic (PZT)	3.5” x 3”	6KV	26 mA
6)	Piezoelectric Ceramics (PZT) with Carbon paint	3.5” x 3”	4.5KV	25 mA

III. DISCUSSION

Soft robotics is an emerging field with strong potential to serve as an educational tool due to its advantages such as low costs and shallow learning curves. Boneless soft robotic fingers cannot apply concentrated forces to pinch a delicate object. Dielectric elastomer actuators (DEAs) can possibly make soft grippers with better force control due to elastic actuation . A DEA is bonded on a passive layer to make a bilayer unmorphed, which can curl like a finger. The grasping of various-shaped objects is one of the most challenging issues in the robotics field. As a solution to this issue, DEAs attract a lot of attention from researchers. The inherent flexibility of DEA enables an intimate contact between an object and a gripper with a DEA, while making an efficient grasping configuration. Also, the lightweight and high energy density of a DEA are important characteristics in achieving a high weight ratio of gripper mass to grasping capability. Based on a simple working principle and large actuation strain of the DEA, different types of DE grippers have been developed with various configurations.

Dielectric elastomers, as an important category of electroactive polymers, are known to have viscoelastic properties that strongly affect their dynamic performance and limit their applications. For demonstrative purposes, a simple material law is proposed under the theoretical framework. With physically uncoupled polarization and deformation, the simple model is equivalent, to some extent, to the approach of adding Maxwell stress to the total stress in the formulation of finite-deformation viscoelasticity while leaving the inelastic stress unchanged. Boneless soft robotic fingers cannot apply concentrated forces to pinch a delicate object. A three-dimensional design of dielectric elastomer (DE) fingers with higher flexural stiffness and close to 90◦voltage-controllable bending for object gripping and pinching. It makes use of tension arch flexures to elevate pre-stretched DEA into a roof shape and thus magnifies the tension-induced moment, 40 times higher than a flat DEA does, to bend a stiff base frame. Such fingers make normally close-grippers to lift a payload 8–9times their weight.

Unexpected breakdown phenomena exist for DEAs. Such phenomena are derived from various factors, such as the material properties of DEAs, the compliant electrode's properties, and surface condition. To decrease the voltage level, the dielectric elastomer can be either multi-layered or processed to thin films. Another approach is the fabrication of a high voltage controller (or an amplifier) that is small and consumes low power to eliminate the hindrance in working voltage generation. According, to current scenario in Robotics Handling System there is no other product using this type of technology. It will also be capable in handling fragile objects which can be destroyed easily. With a Cheaper rate it can be available easily and helpful for medium scale industries. This is useful for society by helping and creating Human like touch Response to the objects. For use in BIONICS to GRASP VERSATILE OBJECTS in industries.

The voltage levels required to perform the actuation depend on the dielectric layer thickness and material, and on the need to maximize the displacement and force output. Typically, layers of silicone 100 um thick are used. Combined with a dielectric strength of 100 V/um, a system designed as such can theoretically withhold about 10 kV. This voltage level thus became the target aimed at for the purpose of this study.

IV. WORKING OF DEAS METHODOLOGY

Here there are two types of method for testing. One is the bilateral prestrained film where there is a circle of certain diameter and a carbon paint is done on both side of material and both side are extended with some broad line, in which one is extended from top and other from bottom. Second method is uniaxially prestrained film, where a single line is stretched on full material.

1

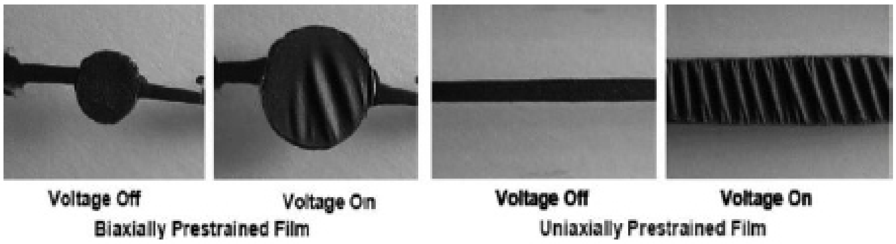

Fig 3. Actual images of fluctuation on voltage on/off.

After this a design is modelled and afterwards it is fabricated. Now here whenever an voltage will be applied to the grippers it will contract and as DC is applied it will now be able to grip the object without any current fluctuation, which helps to hold it safely to its desire position. The carbon paint here helps to stick to the object and avoid droppage of product, still the voltage is deactivated.

14

Fig 4. Concept image of DEA Grippers

V. CONCLUSION AND FUTURE ASPECTS

In this work, we also reported a certain breakdown voltage and current which will result in better understanding of material properties. We also tried out different design, including 4 jaw and 2 jaw mechanism. Finally we wrap-up with 2 jaw due to certain force increment in 4 jaw which has a chance to damage the fragile material. Future studies will result in the grasping ability of soft gripper, trying out exact geometry and its properties, so that we can push this technology into industrial stage.

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