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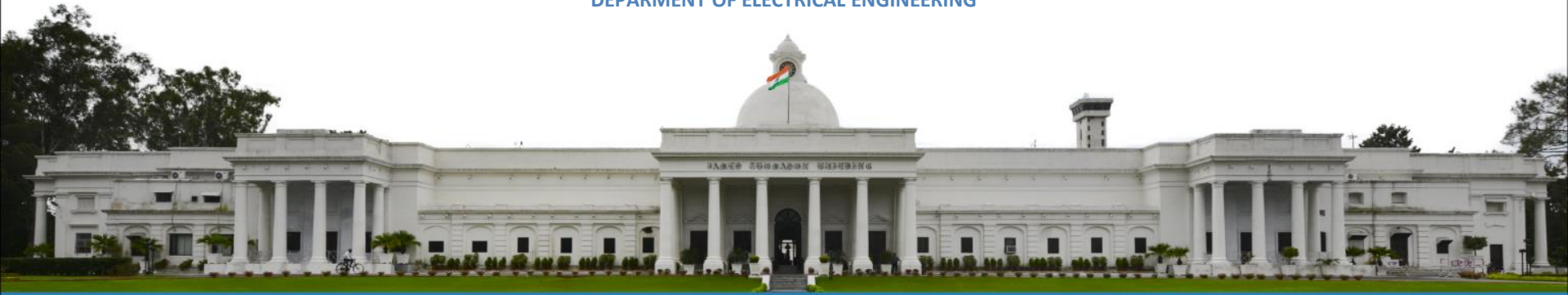
NPTEL ONLINE
CERTIFICATION COURSE

FELIX ORLANDO MARIA JOSEPH

DEPARMENT OF ELECTRICAL ENGINEERING



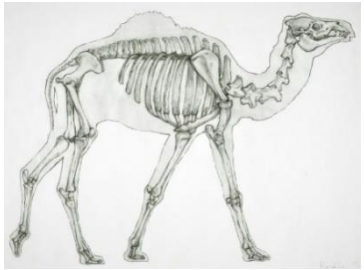
Robotic Exoskeletons: An Introduction

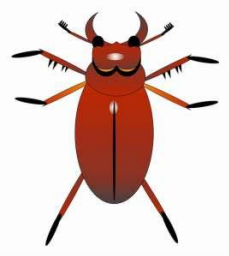
Outline

1. Definition
2. History
3. Types
4. Applications
5. Future Requirements

Exoskeleton - Definition

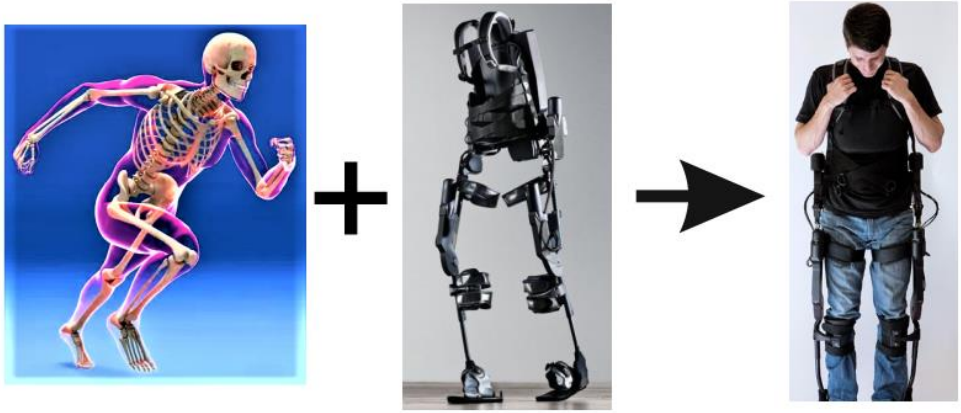
- Humans and Animals have skeletons → Protection, Support, Structure and Movement → of their bodies.
- Muscles → Actuators for facilitating movement of the body parts.
- **Endoskeleton** → Skeleton inside the body.
  - → Living structure.
  - → All vertebrates.
- **Exoskeleton** → Skeleton lying outside the body.
  - → Non-Living structure.
  - → All arthropods.
- Turtle → has both Endoskeleton & Exoskeleton.





Robotic Exoskeleton - Definition

- A mechanical structural frame → to be worn by a human.
- Must provide → Attachment for actuators and power transmission and also comfortable user's body interface.
- Must conform to the body's shape and function.
- Initially developed → Military purpose.
- Benefits:
  - Enhancement of strength and durability of the human wearer.
  - Provides additional support and protection from mobility issues.



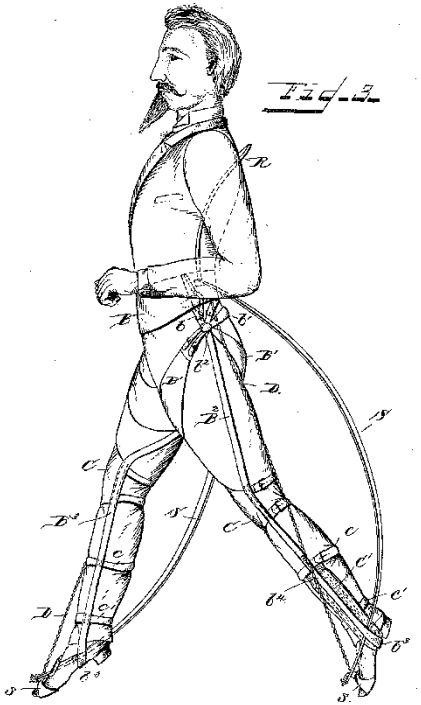
Ekso Bionics Exoskeleton

Exoskeleton - Definition

- **Four Main Functions:**
  - ***Support*** – supporting physically disabled patients in the field of rehabilitation.
  - ***Protection*** – protecting the human operator in hazardous environment such as battle field and nuclear plant.
  - ***Enhancement*** – providing strength to the human operator by acting as assistive equipment.
  - ***Sensing and data fusion*** – acting as the interface between the human operator and the environment. Also makes data fusion from the information received from the human operator.

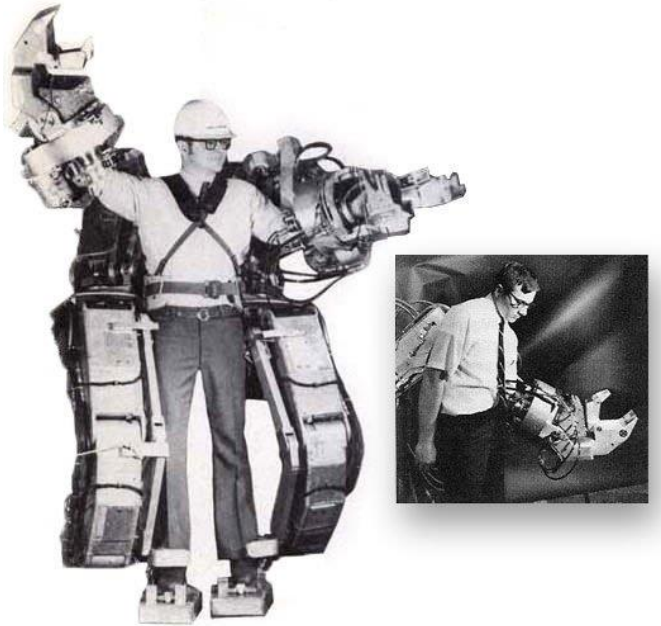
Exoskeleton – Historical Perspectives

- **Yagn's Exoskeleton**
  - First exoskeleton concept for augmenting running and jogging
  - Patented in 1890 – Nicholas Yagn
  - Bow/Leaf spring – on the lateral side of the legs
  - Stance phase – to transfer the body weight to the ground
  - Swing phase – to flex effortlessly



Exoskeleton – Historical Perspectives

- **“Hardiman”**
  - First Powered Exoskeleton – GE (1965-1971)
  - Er. Ralph Mosher – 680 kg
  - Was Unsuccessful
  - Only Arm – 340 kg
  - Not applicable for practical usage



Exoskeleton – Historical Perspectives

- **Mihailo Pupin Exoskeleton**
  - Miomir Vukobratovic
  - Kinematic Walker – hydraulic actuator – hip & knees
  - Partial Active Exoskeleton – pneumatic actuator – hip, knees & ankles
  - Complete Active Exoskeleton – DC motors – torso support
  - Force feedback control

Exoskeleton – Historical Perspectives

- **BLEEX**
  - Prominent exoskeleton under DARPA
  - 4 Actuated DOF (hip-f/e & a/a, knee-f/e & ankle-f/e)
  - Can support upto 75 kg – 0.9m/s
  - Weighs 14 kg

- Current generation focusses on lightweight, compact exoskeleton → **Enhancing agility**

Exoskeleton - Classification

- **Based on *Which Body Part Actuated***
  - ❑ **Whole Body Exoskeletons**
  - ❑ **Upper Extremity Exoskeletons**
  - ❑ **Lower Extremity Exoskeletons**
- **Based on *Powering***
  - ❑ **Powered Exoskeletons**
  - ❑ **Passive Exoskeletons**
  - ❑ **Pseudo-Passive Exoskeletons**
  - ❑ **Hybrid Exoskeletons**
- **Based on *Mobility***
  - ❑ **Fixed Exoskeletons**
  - ❑ **Supported Exoskeletons**
  - ❑ **Mobile Exoskeletons**

Exoskeleton - Applications

- Military Applications
- Medical Applications
- Industrial Applications
- Civilian Applications

Exoskeleton - Applications

- **Military Applications:**
  - For enhancement of strength, agility and endurance of soldiers
  - To perform deep squats, lifting heavy objects and running upto 10mph in uneven terrains
  - For reducing Soldier's response time
  - To protect from strain injuries

Exoskeleton - Applications

- **Military Applications: (cont'd)**

  - ***HULC (Human Universal Load Carrier)***

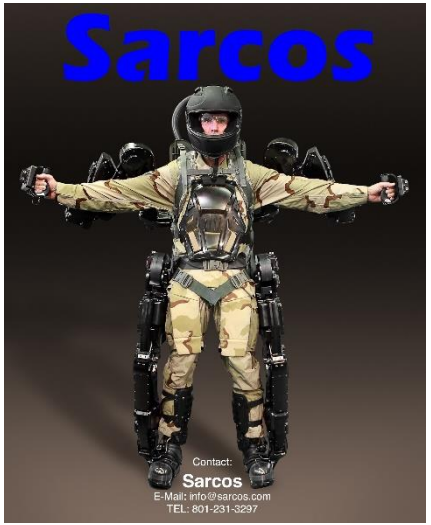
    - Ekso Bionics – 2008
    - Lockheed Martin – Public demonstration – Army Winter Symposium – 2009
    - Supports 20 km range – back and front payloads – max. speed: 11 to 16 km/hr
    - Design: Compact and Customizable – 24 kg & 5'4" to 6'2"

HULC, Ekso Bionics

    - Army and naval drydock workers – load lifter – upto 91 kg
    - Fuel Cell power supply – support 72 hour extended mission

Exoskeleton - Applications

- **Military Applications: (cont'd)**
  - ***Sarcos XOS 2 suit***
    - Public demonstration – 2010
    - Lifting weights at 17:1 – Allows repeated lifting
    - Weighs 95kg → high-strength steel and aluminium, controllers, actuators and sensors
    - Wearer can perform work done – 3 soldiers
    - Lifting – Upto 90kg



XOS 2, SARCOS/RAYTHEON

Exoskeleton - Applications

- **Military Applications: (cont'd)**

  - ***PowerWalk***

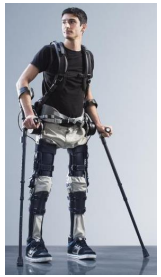
    - Knee exoskeleton – Bionic Power Inc.
    - Walk-recharge capability – reduces the need of carrying backup batteries & battery resupply in the field
    - Intelligent analysis – when to generate high power with less effort

PowerWalk, Bionic Power

Exoskeleton - Applications

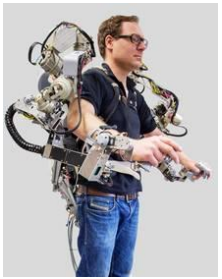
- **Medical Applications:**

  - To assist elderly people and restore motor abilities of stroke patients



Phoenix Medical Exoskeleton

ARMin III Exoskeleton



Capio Exoskeleton

Ekso GT Exoskeleton

Armeo-Spring Arm and Hand Exoskeleton

ReWalk Exoskeleton

Exoskeleton - Applications

- **Medical Applications: (cont'd)**
  - ***PHOENIX Medical Exoskeleton***
    - Enables – Stand up and walk
    - Weighs only 12.25 kg
    - 0.5 m/s speed & 4 hour walking support (for a single charging)
    - Worn while wheel chair seating

PHOENIX Medical Exoskeleton

Exoskeleton - Applications

- **Medical Applications: (cont'd)**
  - ***ReWalk Exoskeleton***
    - Aids the SCI Patients to Stand upright, walk, turn, climb and descend stairs
    - First exoskeleton in US to receive FDA clearance – personal use and with patients
    - Weighs 23.3 kg

ReWalk Exoskeleton

Exoskeleton - Applications

- **Industrial Applications:**

  - In expanding worker capabilities by relieving stress and pressure in his/her neck, knees and back.

Hyundai CEX Exoskeleton

Paexo Exoskeleton

Sarcos Gaurdian Exoskeleton

Exoskeleton - Applications

- **Civilian Applications:**
  - Assisting humans in performing activities of daily living (ADL).

HAL Exoskeleton

Panasonic Exoskeleton

Walking Assist Wearable Robot, Hyundai Motor Group

Requirements

- Ensure Safety
- Light Weight (<15 kg in term of Military applications)
- Affordable (marketed but not widely used)
- Must be durable (self recharging capability)
- Replacement of wheel chairs
- Standard in Industry

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Thank You!