Layman Report of Robotic Exoskeleton Motor Control

Date 3rd July 2019

Alan Yeung

Content

1. Robotic Exoskeleton Background

Robotic exoskeletons could revolutionize the medical industry by giving mobility back to those who had lost it. They could also assist with moving and lifting objects, reducing workplace injury. When it comes to exoskeleton development, two countries in Asia stand apart from the rest: China and Japan. What is taking place within each nation's exoskeleton industry? And what are the key differences between the technology coming from Asia's two largest economies?

The exoskeleton market is still plagued by high costs, preventing them from seeing significant implementation on a consumer level. However, these costs are slowly decreasing, as exoskeletons move past prototype stages into mass production, absorbing research and development costs. The hope is to bring within the reach of far more people.

With the global robotic exoskeleton industry predicted to reach $6.65 billion by 2026, both China and Japan are deeply invested in the development of effective robotic exoskeletons, both for their ability to assist injured or disabled people and to keep aging populations in the workforce longer.

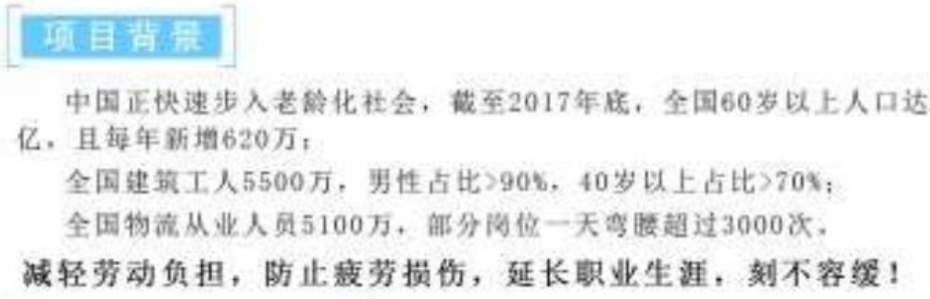
Business Takeaways:

- Both China and Japan view exoskeletons as key in preventing workplace injury and allowing aging workers to stay in the workforce longer.
- The exoskeleton market is predicted to grow quickly in the coming decade, jointly fueled by decreasing costs and expanded consumer product offerings.
- In Japan, exoskeletons are beginning to be covered by insurance providers, a sign that more widespread medical use is likely to occur.

Japanese healthcare exoskeletons

Chinese and Japanese exoskeletons are both designed to address healthcare and industrial challenges — specifically helping the elderly and aging workers. Here, Japan has led exoskeleton advancements for years.

China Exoskeleton Market Outlook


项目背景

中国正快速步入老龄化社会，截至2017年底，全国60岁以上人口达2.4亿，且每年新增620万；

全国建筑工人5500万，男性占比>90%，40岁以上占比>70%；

全国物流从业人员5100万，部分岗位一天弯腰超过3000次。

减轻劳动负担，防止疲劳损伤，延长职业生涯，刻不容缓！

2. Milebot Exoskeleton Robots in brief (Mechanical and Motor assist types)

Flat BLDC Motors are used

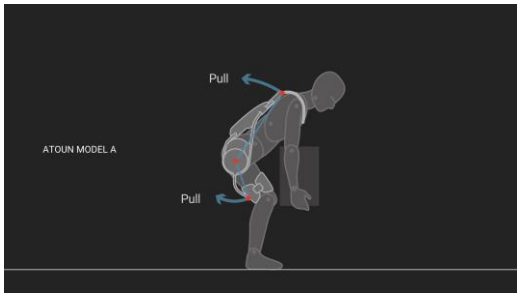
Effective Torque	:	80Nm
Power	:	160W
Voltage	:	24V
Assist Force	:	20kgf max.
Encoder	:	2
Gearhead	:	yes

3. Panasonic Assist Suit AWN-03 Exoskeleton Robot

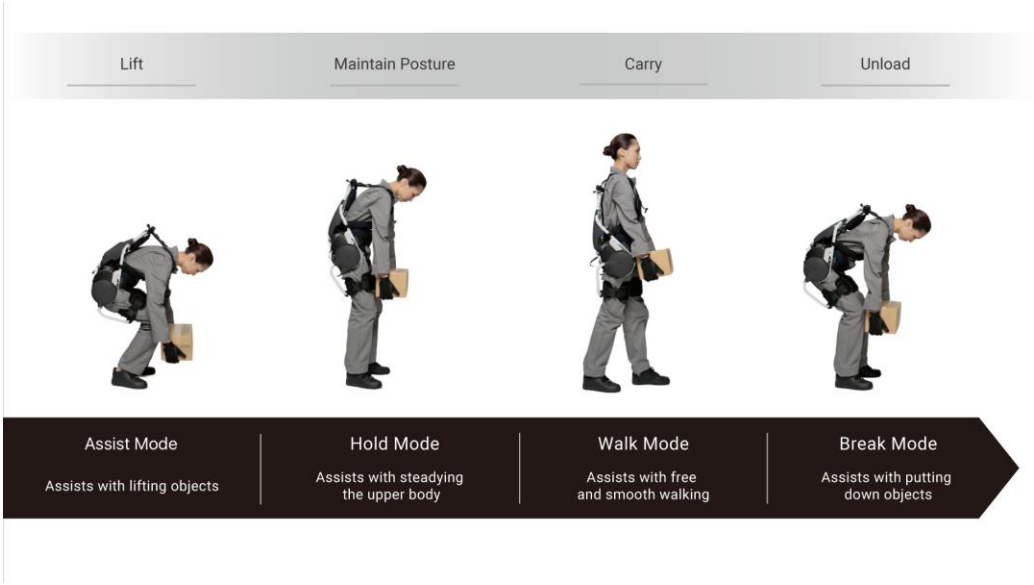
July 6, 2015 18:56 BST

Paanasonic has announced it will start selling mass-produced robot exoskeleton suits from September to help with labour shortages in construction and agriculture. The Assist Suit AWN-03 costs ¥1m and offers a maximum of 15kgforce.Designed to be worn by human adults weighing between 50-80kg, the device weights about 6kg, although this does not include the weight of the battery and the harness.
The exoskeleton has been developed by Activelink, the robot development arm of Panasonic, together with distribution firm Tatsumi Shokai, and Panasonic is keen to offer its exoskeleton suits to be rented, if companies do not need them all the time.
"Human beings, as they age, the one barrier is their strength and their muscles deteriorate. To counteract that, we wanted to build a support system, so that as peopleage, they gain experience. So that they can continue working even when they get older,

AToun Model A



The gears spin according to the user’s waist movements. Pulling the thighs and lifting the upper body from the back, burden on the waist is alleviated.



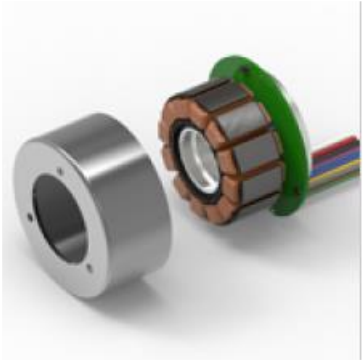
Switching action modes is unnecessary. MODEL A switches on its own by following the user's movements.

Specifications

Size	H77×W48×D27cm	
Stored Size	H60×W45×D27cm	
Weight	6.7kg	Battery excluded
Motor	High torque AC motor exclusive for AWN 03B	2 units equipped
Rechargeable Motor	48.1V Lithium-ion battery	With protective circuit
Hours of Operation	approx. 8 hours	For normal work
Temperature for Use	0 40℃	
Suitable Physique	Height: 155 185cm / Weight: 50 80kg	

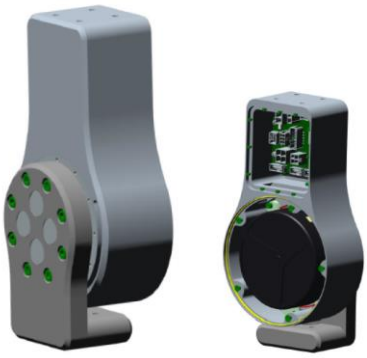
4. Motor Technology for Exoskeleton Solution

a. Flat / Frameless BLDC Motor



Frameless Motors Make for Smaller, Lighter Robots

Frameless motors enable robot designs that are smaller and lighter, Frameless motors, or flat motors without the usual housing, allow for a high power density and reduced robot size and weight. However, they require technical sophistication of the engineers incorporating them into their systems and a clear understanding of how the application shapes the design specifications. (See below example of using Frameless motor on Exoskeleton Robotic application)



Gen.1 Exoskeleton Drive © maxon motor

Exoskeleton joint actuator.
Maxon motor have developed the Exoskeleton Drive GEN.1 for use in hip and knee exoskeletons.
Available from the beginning of October 2017 is a complete joint actuation unit consisting of a Flat brushless DC motor (EC90 flat) with inertia optimised rotor, Internal high resolution 4096 MILE Encoder, planetary gearhead with absolute encoder and EPOS4 position controller with CAN and RS232 interface. Fitting the 17bit SSI absolute encoder directly at the joint rotation to a degree will negate the effect of gearhead backlash giving designers increased positioning accuracy. The unit will deliver 54Nm of continuous torque and 120Nm on a 20% duty cycle. The system can be operated on supplies between 10 and 50V DC and the actuation speed is up to 22rpm.

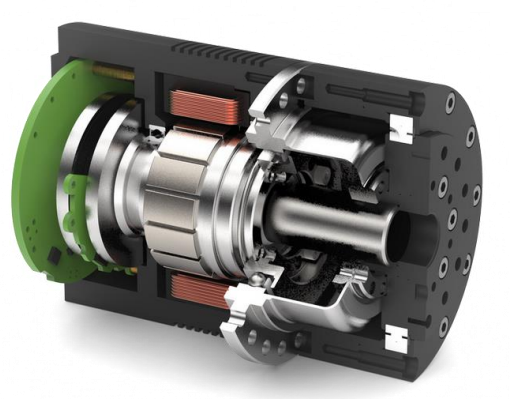
b. AC Servomotor

RDrive servomotor

Most servomotor manufacturers produce a housed brushless motor coupled with an encoder. They call it a servomotor. Powered by DC current, the motor is controlled with the help of an external servo controller kit (sometimes called servo drive). In case you need a gear motor kit, you connect a gearhead to the motor.

Servomotors RDrive, Featuring integrated controller, encoder, and harmonic gear drive

RDrive is a hollow shaft compact servomotor. A frameless motor, 2 absolute position magnetic encoders, a strain-wave gear and a motor controller are all placed in a single housing. Though RDrive is a small servomotor (53-115 mm diameter), it can boast high torque density (up to 333 Nm), high power (up to 450W), and high precision (0.01 mm).



RDrive servo motors are intended for commercial and industrial use to ensure high-precision rotary motion. **Figure 1-1** is an exploded view of an RDrive servomotor in a housing.

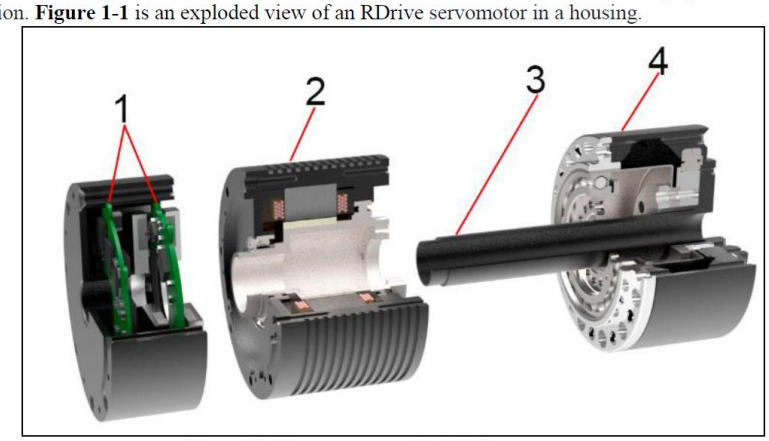


Figure 1-1: The components of an RDrive servo motor

(1)	Two printed circuit boards (PCBs) connected with each other by means of the BiSS interface. One of the PCBs incorporates a controller and the other—two encoders.
(2)	A frameless brushless alternating current (AC) motor comprising a rotor and a stator, as well as a negative temperature coefficient (NTC) thermistor fitted into the stator winding.
(3)	A hollow shaft, which you can use for laying the cables to connect the servo to a machine.
(4)	A strain-wave gearhead that reduces rotation speed (RPM) and increases motor torque.

Harmonic Strain Wave Gear in RDrive Servos

The RDrive series features integrated harmonic gearboxes that use strain-wave gear technology. With the gear ratio of 1:100 and an almost-zero backlash, the technology enhances the performance of our servo motors. This gives you precise motion control and high-torque output.

Why a servo needs a gearbox

When used in a combination with a servo motor, a gearbox, also called a gearhead or a speed reducer, allows for the following:

- Increasing the motor torque.
- Reducing the motor speed.
- Balancing out the motor inertia against that of the load.

The effects are due to the gears in the servo gearbox creating a gear ratio. Applying the gear ratio of 1:100 to a motor generating 2 N·m of torque results in the output torque of 200 N·m. Similarly, if a motor runs at 4,000 RPM, the same ratio will reduce the speed to 40 RPM.

5. Comparison between MileBot Robot AB1 and Panasonic Assist Suit AWN-03B Motor Solution

	Panasonic AWN-03B	**MileBot AB1**
Motor Type	High Torque AC Motor x2	Frameless BLDC Motor x2
Speed Reducer	Harmonic drive x2	External Gearbox x2
Gearhead encoder	17 bit Absolute encoder x2	Tamagawa incremental Encoder x2
Motor position encoder	17 bit Absolute encoder x2	2500 line Incremental Encoder x2
Supply Voltage	48V	24V
Assist Force	15Kgf	20Kgf
Weight * Battery Excluded	6.7Kg	> 10Kg
Drive	AC Servo drive x2	BLDC Drive x2
Motor/Drive Solution Cost	> HKD 45,000	> HKD 30,000

6. Area for Improvement of Milebot Exoskeleton Robot Motor solution

a. Motor/ Drive Cost Reduction

   i. The Maxon Flat BLDC motor EC90 alone. cost HKD 1,600.00 with Internal high resolution 4096 MILE Encoder cost (HKD 500)

   ii. An external gear box + Tamagawa cost (HKD4,500.00)

   iii. EPOS4 position controller with CAN and RS232 interface cost (HKD 5,500.00),

b. Size and Weight can be reduced by higher level of integration using all in one Motion Control solution

   i. The Motor , Gearbox, Drive were not in one housing

   ii. Drives and Central Control board are in separated boards

   iii. Lighter motor selection

c. Longer battery life by enhanced motor technology

   i. Energy efficient motor and intelligent motion control to maximize torque

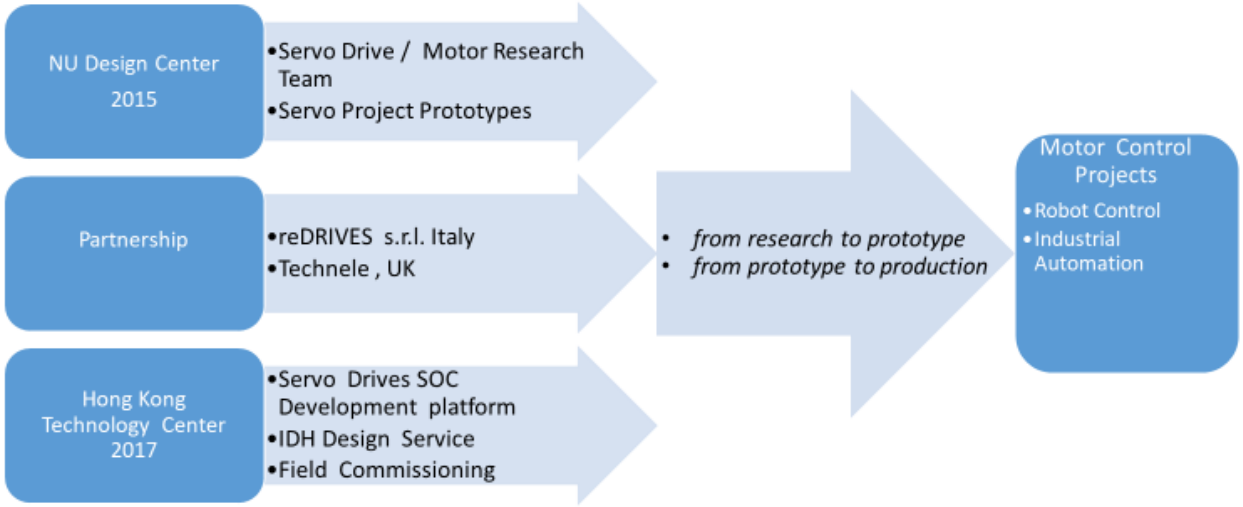
7. Elements motion limited , HK /UK

Elements Motion Background & Charter

- Elements Motion Limited
  - Registered limited company in UK since June 2010
  - Office at Nottingham science Park
- Best Motion Technology / Nottingham University Innovation Center projects Management
  - Responsible for the contract, invoice auditing, payment
  - Project status and progress management
  - IP , copy write protection and Patent registration
- Collaborate with UK design houses to develop advanced Motor & Drive products for the applications in China.

ELEMENTS

Elements Motion Ltd Established in 2010



ELEMENTS

深圳市迈步机器人科技有限公司是一家由海归博士团队和资深机器人行业从业者创立的医疗康复机器人科技公司。公司专注于打造智能康复体系，通过机器人、物联网、大数据等技术提升康复医疗的效率和效果。公司围绕其核心技术——基于柔性驱动器的机器人交互技术，研发了包括下肢康复外骨骼机器人在内的数款医疗康复机器人产品。迈步机器人团队在康复机器人领域拥有世界顶尖的技术水平，拥有数十项发明专利，具有强大的研发能力和创新理念。

公司发展历程

2016-09 公司注册成立 – 深圳市迈步机器人科技有限公司正式成立。

2016-12 大赛获奖 – 公司项目获得 2016 南山创业之星大赛团队组第三，从 3000 多个项目中突围而出，获得资本的青睐。

2017-01 规模扩大 – 办公场地搬迁 由南山软件产业基地搬迁至南山区留学生创业大厦，享受海归人员创业办公场地优惠政策，办公场地扩大，人员迅速增加，公司进入快速发展阶段。

2017-01 技术实力获得市场认可 – 与某上市医疗器械企业取得产品研发合作关系。

2017-04 获得天使轮融资 – 投资方为：联想创投、泰有、泰益。

2017-05 创始人获得深圳市“孔雀人才”C 类人才认定 – 公司创始人陈功利用自身的学术专业度获得 2017 年深圳市海外高层次海外留学人才（孔雀计划）中人才认定 C 类。

2017-10 被评为“最具投资价值企业”之一 – 获得 Venture50 新芽榜：2017 中国最具投资价值企业 50 强。

2017-11 举行产品发布会 – 第一场外骨骼机器人产品发布会在深圳福田马可孛罗好日子酒店隆重举行。

2017-11 参展高交会 – 出席深圳第 19 届高交会的展览。

2017-12 中国人工智能机器人 CEO 峰会获奖 – 迈步机器人荣获由中国人工智能机器人产业联盟（CAIA）颁发的“2017 年度中国服务机器人十大技术创新产品”和“2017 年度中国医疗康复机器人最佳品牌”。

2018-03 迈步 CEO 荣获“年度极客人物” – 迈步 CEO 陈功博士荣获由深圳物联评选出的“年度极客人物”。

2018-04 参展中国国际医疗器械博览会 – 迈步机器人在此届中国国际医疗器械博览会上展出。

2018-04 完成数千万元 PerA 轮融资 – 投资方为：分享投资、联想创投。

2018-08 创始人入选福布斯 30U30 – 迈步机器人创始人兼 CEO 陈功博士入选 2018 福布斯中国 30 位 30 岁以下精英榜医疗健康领域榜单。

2018-08 入选 2018Venture50 新芽榜 – 迈步机器人入选 2018 中国最具投资价值企业 50 强。

2018-11 国家高新技术企业 – 迈步机器人申请的国家高新技术企业称号进行公示。

2018-11 获批深圳市留学人员创业前期费用一等资助 – 迈步机器人经深圳市人力资源与社会保障局批准获得深圳市出国留学人员创业前期费用补贴补贴一等资助 100 万。

2018-11 获批广东省第二类创新医疗器械特别审批申请 – 迈步机器人产品“下肢外骨骼康复训练机器人”经广东省药品监督管理局批准，同意按照《广东省第二类创新医疗器械特别审批程序（试行）》进行审批。

2019-01 搬家至深圳国家实验室大楼 – 迈步机器人由留学生创业大厦搬入深圳国家实验室大楼。