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Development Outline of the HUBO2

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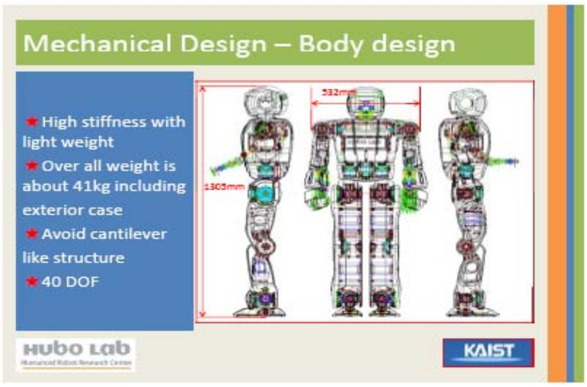
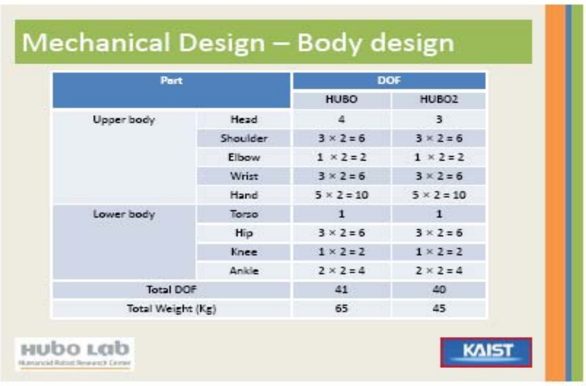
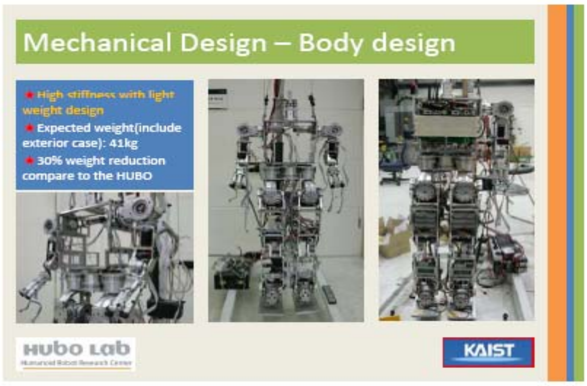
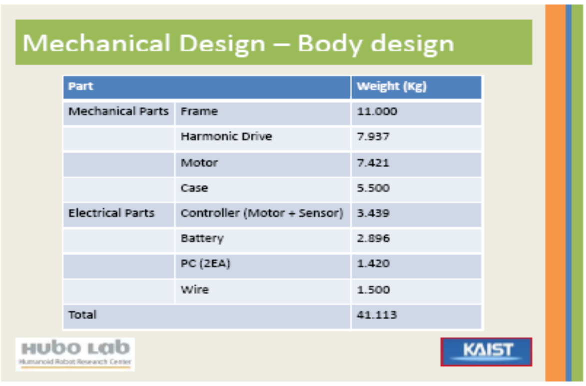


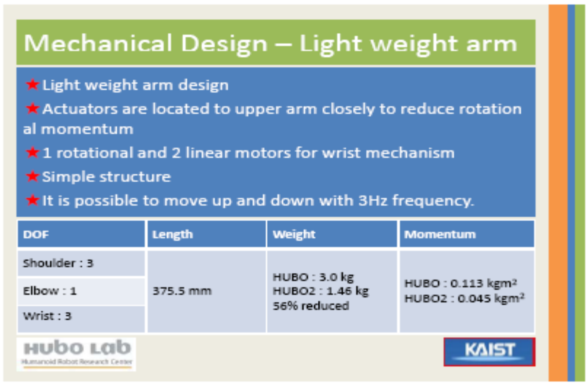


Part		DOF	
		HUBO	HUBO2
Upper body	Head	4	3
	Shoulder	3 × 2 = 6	3 × 2 = 6
	Elbow	1 × 2 = 2	1 × 2 = 2
	Wrist	3 × 2 = 6	3 × 2 = 6
	Hand	5 × 2 = 10	5 × 2 = 10
Lower body	Torso	1	1
	Hip	3 × 2 = 6	3 × 2 = 6
	Knee	1 × 2 = 2	1 × 2 = 2
	Ankle	2 × 2 = 4	2 × 2 = 4
Total DOF		41	40
Total Weight (Kg)		65	45





Part		Weight (Kg)
Mechanical Parts	Frame	11.000
	Harmonic Drive	7.937
	Motor	7.421
	Case	5.500
Electrical Parts	Controller (Motor + Sensor)	3.439
	Battery	2.896
	PC (2EA)	1.420
	Wire	1.500
Total		41.113



DOF	Length	Weight	Momentum
Shoulder : 3 Elbow : 1 Wrist : 3	375.5 mm	HUBO : 3.0 kg HUBO2 : 1.46 kg 56% reduced	HUBO : 0.113 kgm² HUBO2 : 0.045 kgm²


Mechanical Design – Adaptive hand
★Various wrist movements
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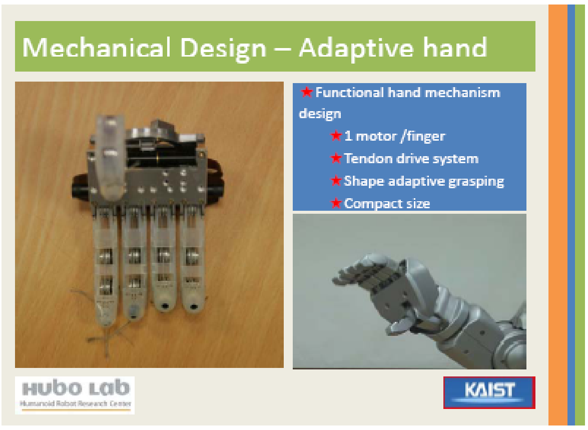
Mechanical Design – Adaptive hand
★Functional hand mechanism design
★1 motor /finger
★Tendon drive system
★Shape adaptive grasping
★Compact size
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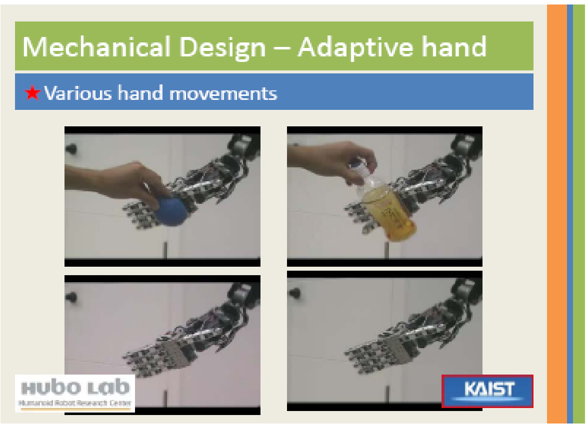
Mechanical Design – Adaptive hand
★Various hand movements
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Mechanical Design – Adaptive hand
★Handshake movements
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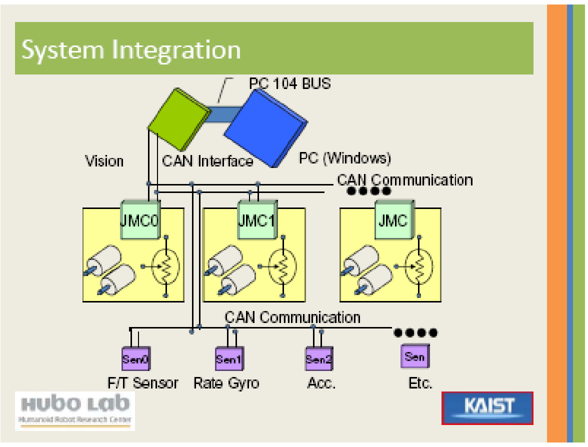
System Integration
PC 104 BUS
Vision
CAN Interface
PC (Windows)
CAN Communication
JMC0
JMC1
JMC
CAN Communication
Sen0
Sen1
Sen2
Sen
F/T Sensor
Rate Gyro
Acc.
Etc.
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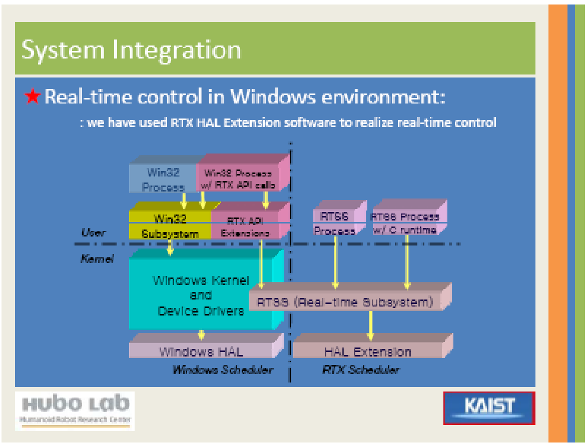
System Integration
★Real-time control in Windows environment:
: we have used RTX HAL Extension software to realize real-time control
Win32 Process
Win32 Process w/ RTX API calls
Win32 Subsystem
RTX API Extensions
RTSS Process
RTSS Process w/ C runtime
User
Kernel
Windows Kernel and Device Drivers
RTSS (Real-time Subsystem)
Windows HAL
HAL Extension
Windows Scheduler
RTX Scheduler
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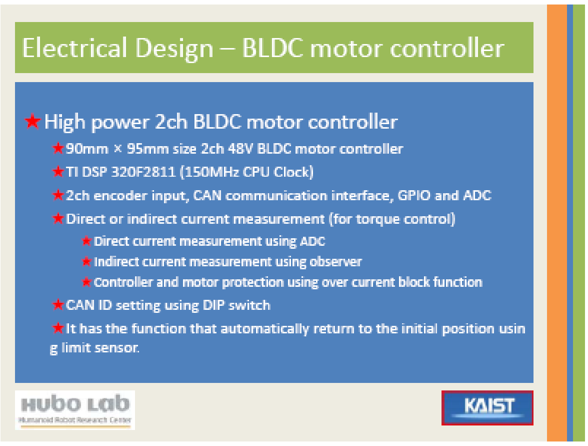
Electrical Design – BLDC motor controller
★High power 2ch BLDC motor controller
★90mm × 95mm size 2ch 48V BLDC motor controller
★TI DSP 320F2811 (150MHz CPU Clock)
★2ch encoder input, CAN communication interface, GPIO and ADC
★Direct or indirect current measurement (for torque control)
★Direct current measurement using ADC
★Indirect current measurement using observer
★Controller and motor protection using over current block function
★CAN ID setting using DIP switch
★It has the function that automatically return to the initial position using limit sensor.
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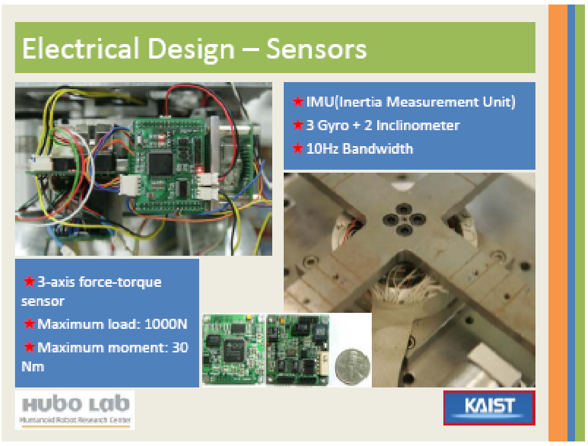
Electrical Design – Sensors
★IMU(Inertia Measurement Unit)
★3 Gyro + 2 Inclinometer
★10Hz Bandwidth
★3-axis force-torque sensor
★Maximum load: 1000N
★Maximum moment: 30 Nm
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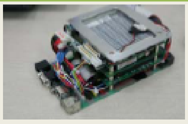
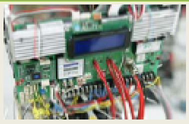
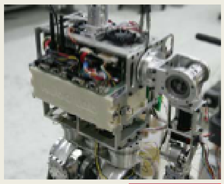
Electrical Design – Other electrical parts

- PC module
  - PC-104 type Intel 1GHz CPU
  - 2ch CAN, Wireless lan, sound port, USB and so on
- Power distribution module
  - Selectable external power or internal battery
  - 48V to 48V, 12V and 5V
- Battery module
  - Lithium-Ion Polymer
  - 48 Volt – 8 Ampere

Electrical Design – Other electrical parts

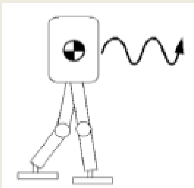


Stretched Leg Walking Algorithm – Motivation

Stretched leg Walking

- Advantage
  - Similar to human walking
  - Reduction of load on actuator
  - Efficient walking in a point of view (energy, speed)
- Disadvantage
  - Singularity problem to solve inverse kinematics
  - Large landing impact.

Pelvis height is varying.



Stretched Leg Walking Algorithm – Experiment

Stretched leg walking realize **HIGH SPEED WALKING**.

Stretched Leg Walking Algorithm – Experiment

Energy consumption per each step.

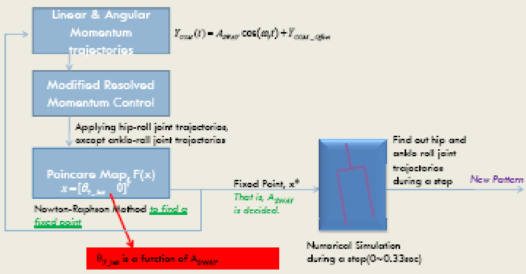
Step Length	Bent knee walking (E1)	Stretched leg walking (E2)	E2/E1
200mm	74 (J)	61.4 (J)	83 %
	2.04 (A)	1.60 (A)	
300mm	146.9 (J)	83.4 (J)	56 %
	3.66 (A)	2.15 (A)	

Stretched leg walking is more **EFFICIENT** than bent knee walking.

Running algorithm

Running Pattern Generation

3) Y-directional Pattern Generation in the Frontal Plane



Running algorithm – 3D running

- Velocity : 3 km/h
- Flying time : 40msec

Running algorithm – Stabilization