TECHNICAL GUIDE

the world's most advanced humanoid robot

CONTENTS

ROBOT DEVELOPMENT

AIMING FOR FUNCTION IN THE HUMAN LIVING SPACE – HONDA WANTS TO CREATE A PARTNER FOR PEOPLE, A NEW KIND OF ROBOT THAT FUNCTIONS IN SOCIETY.

CREATING NEW MOBILITY

Following in the steps of Honda motorcycles, cars and power products, Honda has taken up a new challenge in mobility - the development of a two-legged humanoid robot that can walk.

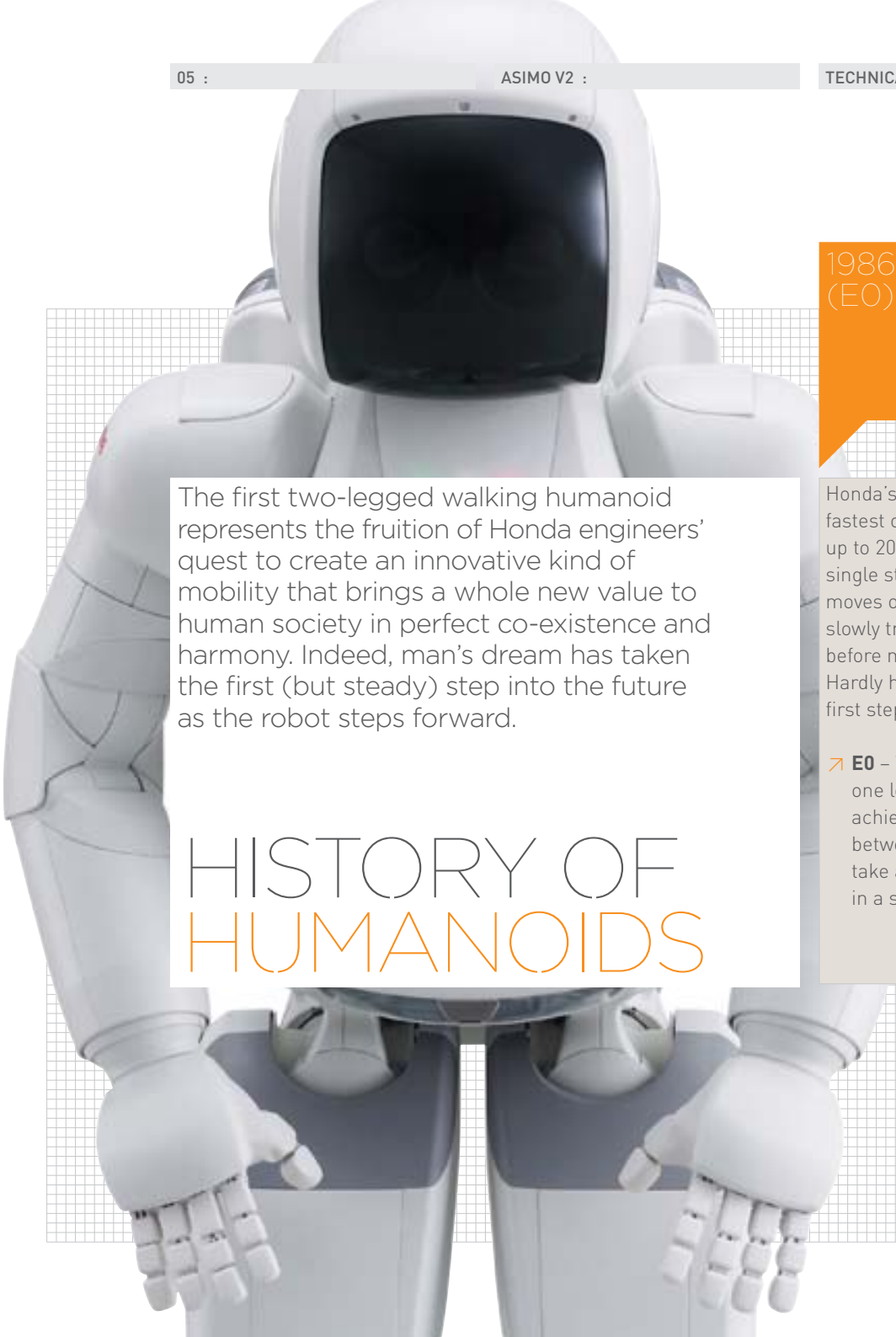
THE CONCEPT BEHIND HONDA'S ROBOT R&D

The main concept behind Honda's robot R&D was to create a more viable mobility that allows robots to help and live in harmony with people. Research began by envisioning the ideal robot form for use in human society.

The robot would need to be able to manoeuvre between objects in a room and be able to go up and down stairs. For this reason it had to have two legs, just like a person.

In addition, if two-legged walking technology could be established, the robot would need to be able to walk on uneven ground and be able to function in a wide range of environments.

Although considered extremely difficult at the time, Honda set itself this ambitious goal and developed revolutionary new technology to create a two-legged walking robot.



The first two-legged walking humanoid represents the fruition of Honda engineers' quest to create an innovative kind of mobility that brings a whole new value to human society in perfect co-existence and harmony. Indeed, man's dream has taken the first (but steady) step into the future as the robot steps forward.

HISTORY OF HUMANOIDS

1986 (E0)

Honda's first robot E0 isn't the fastest of walkers. In fact it takes up to 20 seconds to complete a single step. That's because E0 moves one foot forward, then slowly transfers its balance before moving the other foot. Hardly human-like, but a worthy first step.

- **E0** – Walking by putting one leg before the other is achieved. However, E0 takes between 5 to 20 seconds to take a step and can only walk in a straight line.

1987 – 1991 (E1, E2, E3)

Meet E1, E2 and E3 – the dynamic walking robots. Rather than balancing before moving, these robots lean into their next step, shift their weight and move the other foot forward to catch themselves, just like you or I do. They work fine on a completely flat surface. But not so fine on anything else.

- **E1** – This early prototype of later models walks at 0.25 km/h and has a distinct movement between each leg.
- **E2** – The first model that can walk 'dynamically'. E2 shifts its weight forward, and leans into the next step, achieving 1.2 km/h.
- **E3** – E3 features 'thigh-like' legs and is further refined to walk at a much more human 3 km/h.

1991 – 1993 (E4, E5, E6)

E4, E5 and E6 are a real leap forward. They feature 'posture control' technologies that allow them to compensate if they become off-balance. In other words they can easily walk on an incline, up stairs, or over uneven surfaces. They're still not the most friendly looking robots, but they're certainly masters of walking.

- **E4** – Knee length is increased to 40 cm to allow E4 to simulate quick human steps. This results in a walking speed of 4.7 km/h.
- **E5** – E5 features posture control technologies to stabilise walking. This allows it to walk on sloping surfaces and steps.
- **E6** – E6 has autonomous control of balance so it can cope with and react to difficult and uneven surfaces.

1993 – 1997 (P1, P2, P3)

With their heads, bodies and arms, Prototypes P1, P2 and P3 certainly look more like robots. They can turn on switches, pick up and carry objects, even push carts. And by P2 they can even do it wirelessly. Arms and a body also help with balance. Push P2 and he won't fall over. You'll also see they're getting smaller. P1's height of over 1.9 metres is hardly a 'friendly' size for a robot.

- **P1** – The first 'human' prototype robot features an upper body and arms. P1 can operate switches and pick up and carry objects.
- **P2** – P2 features a plastic 'skin' and is completely wireless. It stuns the public with its realistic movement.
- **P3** – P3 is a completely independent humanoid robot. Its decentralised control systems and new component materials means it is smaller and lighter than its predecessors.

2000 – 2005 (ASIMO v1)

This is ASIMO. ASIMO can walk upstairs, walk backwards, balance on one foot, even recognise faces. What makes ASIMO so different is Predicted Movement Control. Unlike other robots that have to stop and shuffle to change direction, ASIMO can turn without stopping. You'll also notice ASIMO has a more attractive design and is a much more people-friendly 120 cm tall.

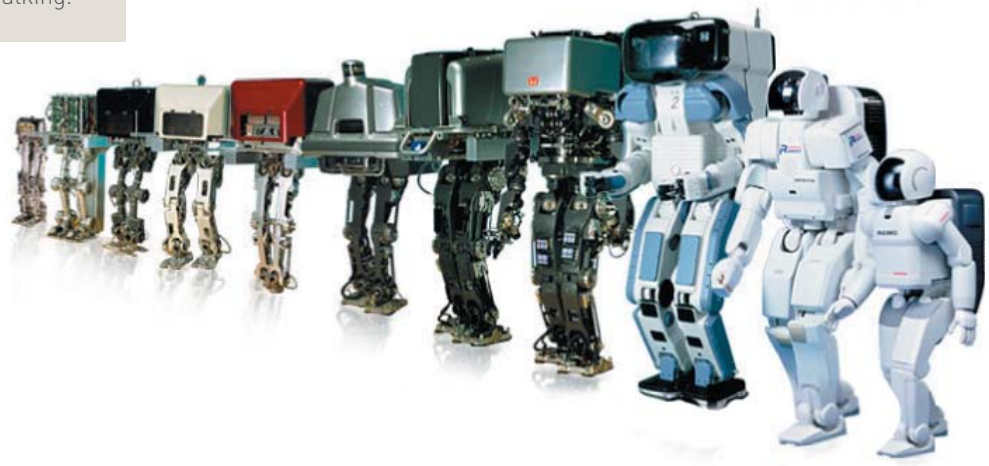
- **ASIMO v1** – Lighter, smaller, more flexible and more human-like – ASIMO is the first robot to feature predicted movement control which allows it turn without stopping.

2005 – Current (ASIMO v2)

ASIMO is continually being developed, and in 2005 a new more mobile version is 'born'. ASIMO can run, turn while running, and even perform basic receptionist tasks. But what next? The dream for ASIMO now is 'brain like' intelligence. That means learning by sensing and experiencing its environment – something only a 'walking' robot can do.

- **ASIMO v2** – ASIMO can run at 6 km/h and even turn while running. It can also perform basic reception duties and hold hands while walking.

The concept behind Honda's Robot R&D
... to create a more viable mobility that allows robots to help and live in harmony with people.

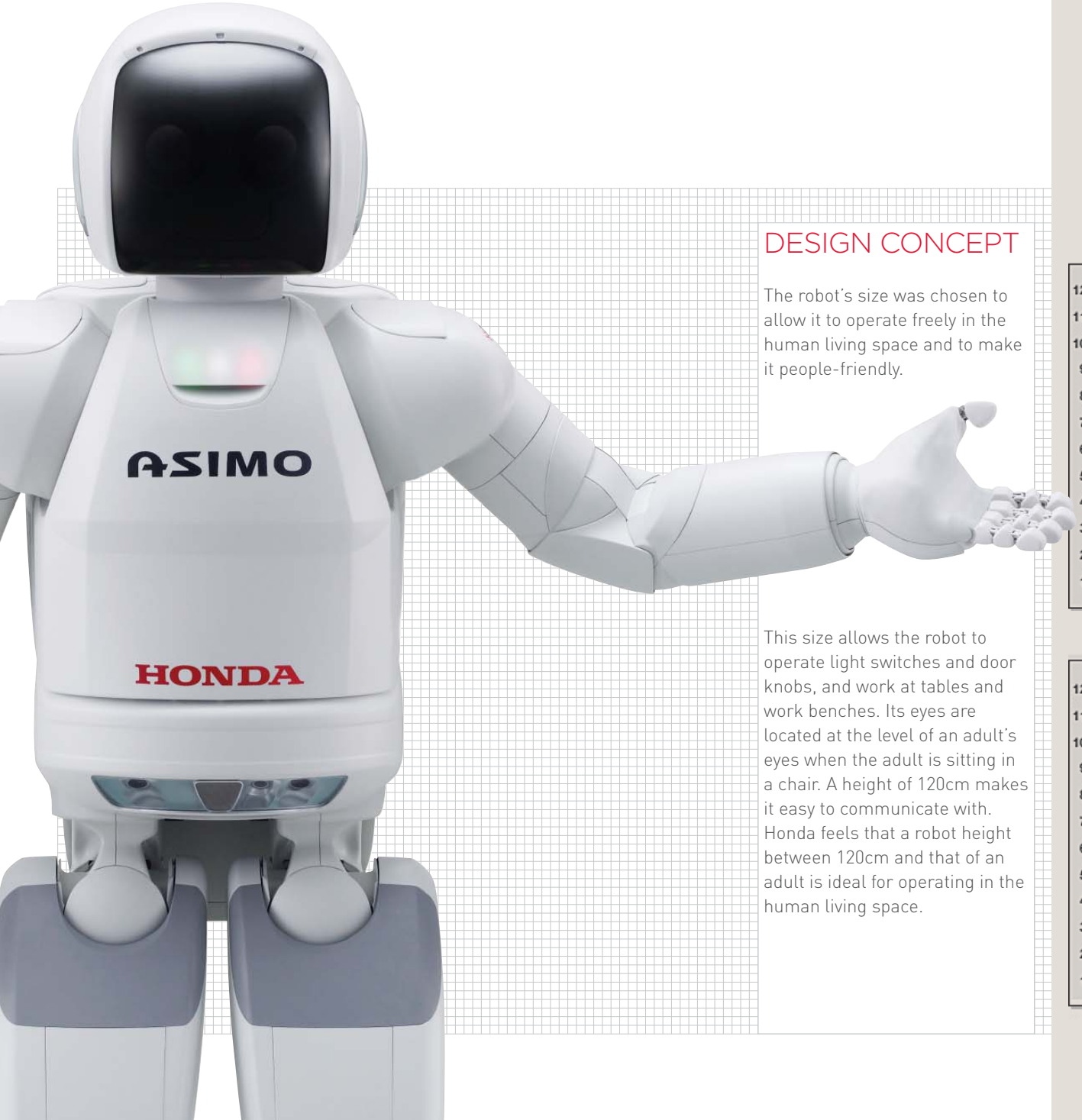


ASIMO v1

OVERVIEW

As exemplified by P2 and P3, the two-legged walking technology developed by Honda represents a unique approach to the challenge of autonomous locomotion. Using the know-how gained from these prototypes, research and development began on new technology for actual use. ASIMO represents the fruition of this pursuit. ASIMO was conceived to function in an actual human living environment in the near future. It is easy to operate, has a convenient size and weight and can move freely within the human living environment, all with a people-friendly design.

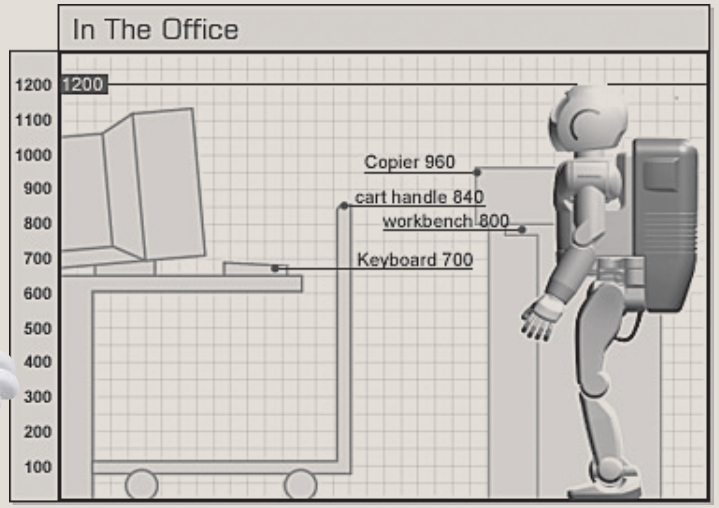
ASIMO was conceived to function in an actual human living environment in the near future.

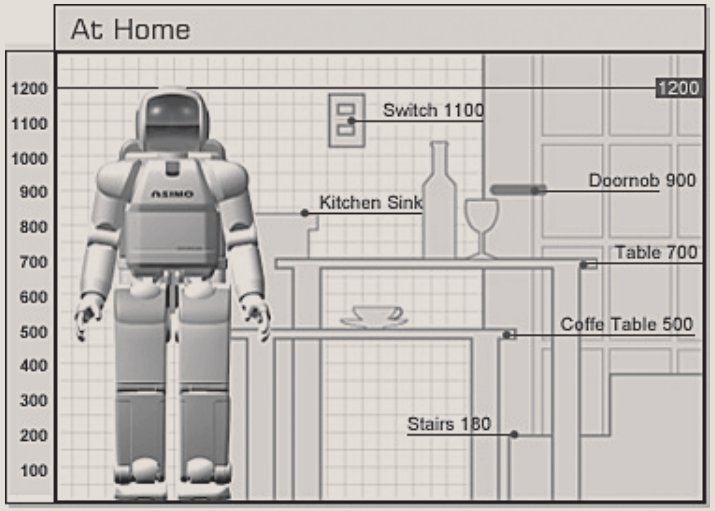


DESIGN CONCEPT

The robot's size was chosen to allow it to operate freely in the human living space and to make it people-friendly.

This size allows the robot to operate light switches and door knobs, and work at tables and work benches. Its eyes are located at the level of an adult's eyes when the adult is sitting in a chair. A height of 120cm makes it easy to communicate with. Honda feels that a robot height between 120cm and that of an adult is ideal for operating in the human living space.

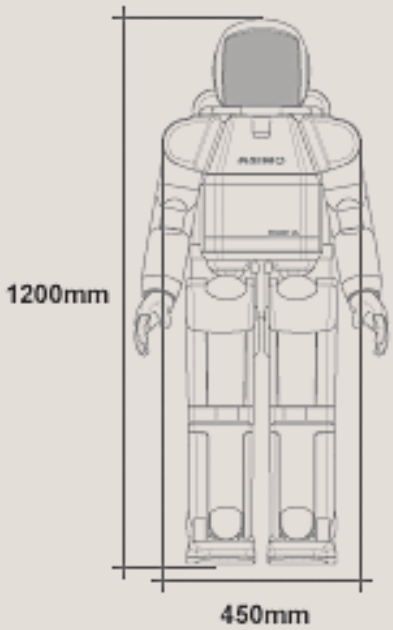




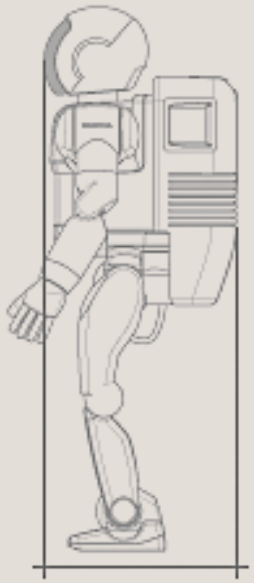
* The above heights are examples to serve as a reference(mm).

SPECIFICATIONS

Front



Side



Specifications

Weight		52kg
Walking Speed		0-1.6km/h
Walking Cycle		Cycle Adjustable,Stride Adjustable
Grasping Force		0.5kg/hand(5-finger hand)
Actuator		Servomotor+Harmonic Speed Reduver +Drive Unit
Control Unit		Walk/Operating Control Unit, Wireless Transmision Unit
Sensors	Foot	6-Axis Foot Area Sensor
	Torso	Gyoscope &Acceleration Sensor
Power Section		38.4V/10AH(Ni-MH)
Operationg Secion		Workstation and portable Controller

Degrees of Freedom (For Human Joints)

Head	Neck Joint(U/D,RT)*1	2DOF
Arm	Shoulder Joint(F/B,U/D,RT)	3DOF
	Elbow joint(F/B)	1DOF
	Wrist joint(RT)	1DOF
		5DOF X 2arms=10DOF
Hand	5fingers(Grasping)	1DOF
		1DOF X 2hands=2DOF
Leg	Hip joint(F/B,L/R,RT)	3DOF
	Knee joint:(F/B)	1DOF
	Ankle joint:(F/B,L/R)	2DOF
		6DOF X 2legs=12DOF

*1
F/B : Forward/Backward U/D : Up/Down
L/R : Left/Right RT * Rotation DOF: Degrees of Freedom

WALKING

SMOOTHER AND MORE STABLE WALKING

The introduction of intelligent, real-time, flexible-walking technology allowed ASIMO to walk continuously while changing directions, and gave the robot even greater stability in response to sudden movements.

Earlier Ways of Walking

1 In the past,different patterns were used for straight walking and for turning,and a slight pause was required during the transition.

For Robots up to P3

Straight(A) → Temporary Pause → Turn(B) → Temporary Pause → Straight(C)

For example,when the P3 robot turned sharply when walking straight, its movement was awkward because it had to stop to make the turn.

2 Walking stripes (time per step) were limited to only a few variations.

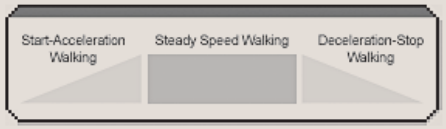
Because each walking pattern has a different stride(time per step), the robot could not change its stride(time per step) flexibly.

Creating Earlier Walking Patterns

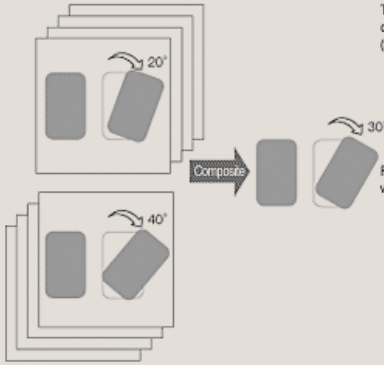
Earlier walking technology allowed roughly two different walking patterns.

A Straight (foot lifting with toes upward and landing on heel)

When walking in a straight line, the robot followed an ordered pattern of start-acceleration walking, steady speed walking and deceleration-stop walking, all of which was stored as time series data.

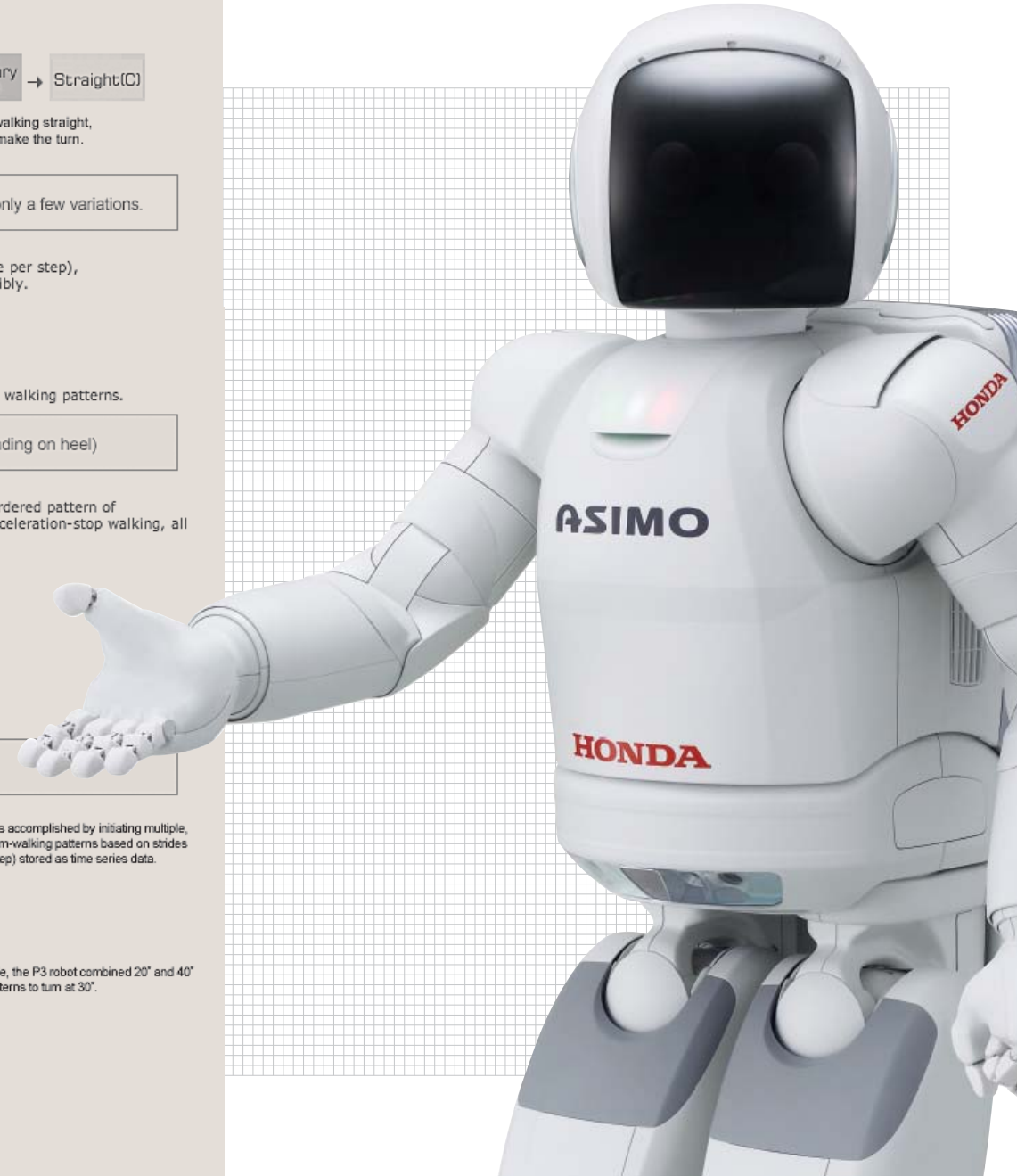


B Turning (Direction-Changing Walking)



Turning was accomplished by initiating multiple, different, turn-walking patterns based on strides (time per step) stored as time series data.

For example, the P3 robot combined 20° and 40° walking patterns to turn at 30°.

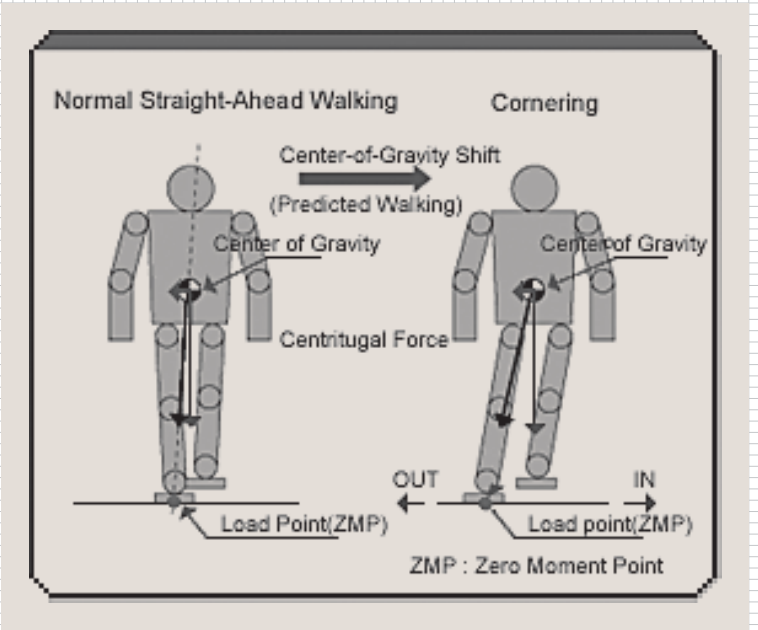


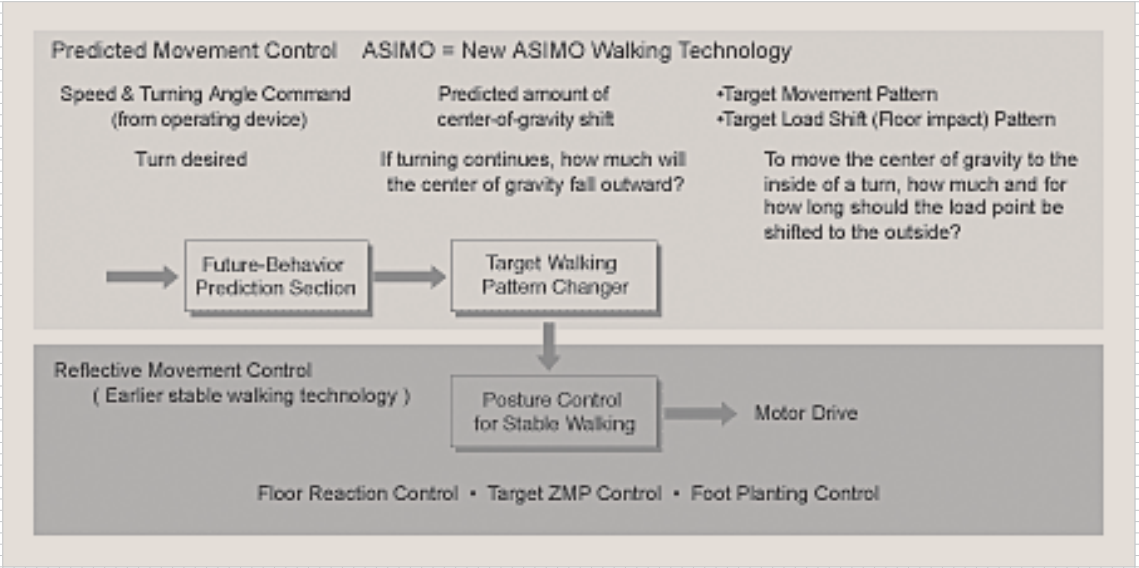
INTELLIGENT WALKING TECHNOLOGY

New ASIMO Walking Technology features a predicted movement control added to the earlier walking control technology. This new two-legged walking technology permits more flexible walking. As a result, ASIMO now walks more smoothly and more naturally.

Creating Prediction Movement Control

When human beings walk straight ahead and start to turn a corner, they shift their centre of gravity toward the inside of the turn. Thanks to New ASIMO Walking Technology, ASIMO can predict its next movement in real time and shift its centre of gravity in anticipation.





Control Block Map

The Future of Intelligent Walking Technology

Thanks to Intelligent Walking Technology, ASIMO can change its walking smoothly and continuously at any time. Intelligent Walking Technology allows robots to exist more easily in the human living environment. This technological development will allow robots of the future to work in harmony with people while avoiding obstructions on their own.

Intelligent, Real-Time, Flexible Walking Achieved!

1 Continuous movement possible without pauses.

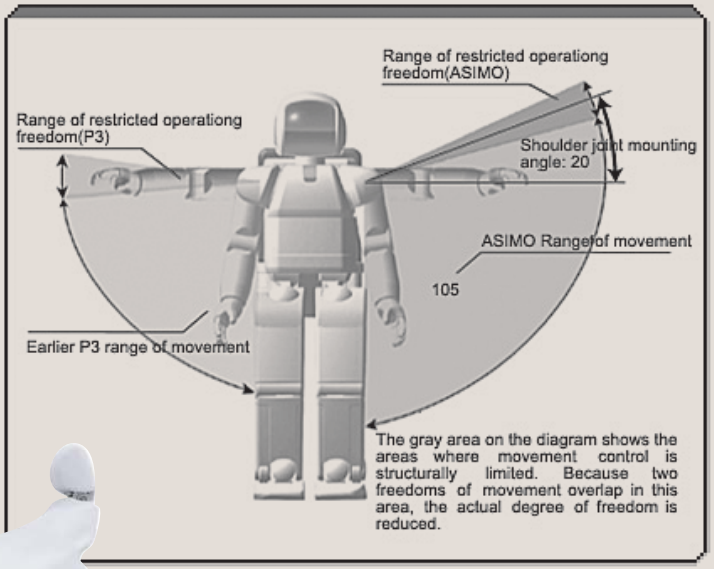
Straight Ahead → Turning → Straight Ahead

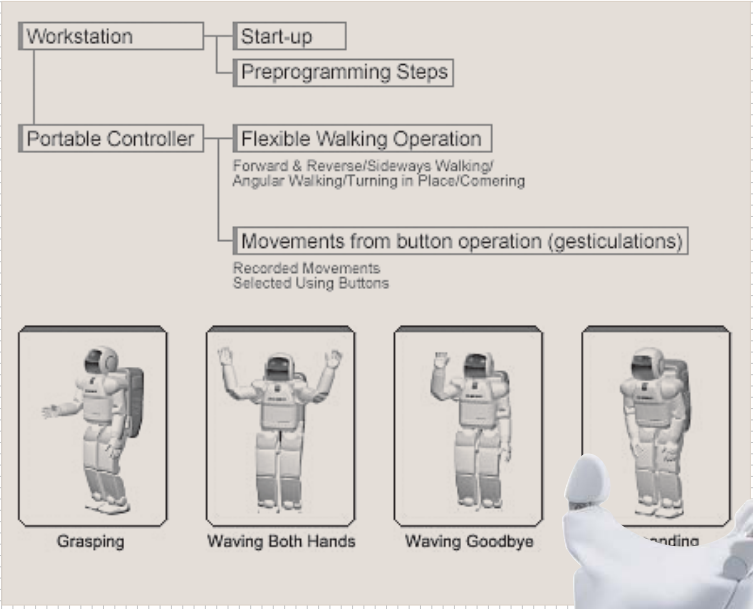
Because continuous flexible walking is possible, ASIMO can move and walk rapidly and smoothly at all times.

2 In addition to changes in foot placement and turning ,the stride (time per step can be changed freely

Robots up to the P3 turned according to combinations of stored walking patterns.ASIMO creates walking patterns in real time and can change foot placement and turning angle at will. As a result, it can walk smoothly in many directions. In addition, because stride (time per step) can also be changed freely, ASIMO's movements are much more natural.

Arms



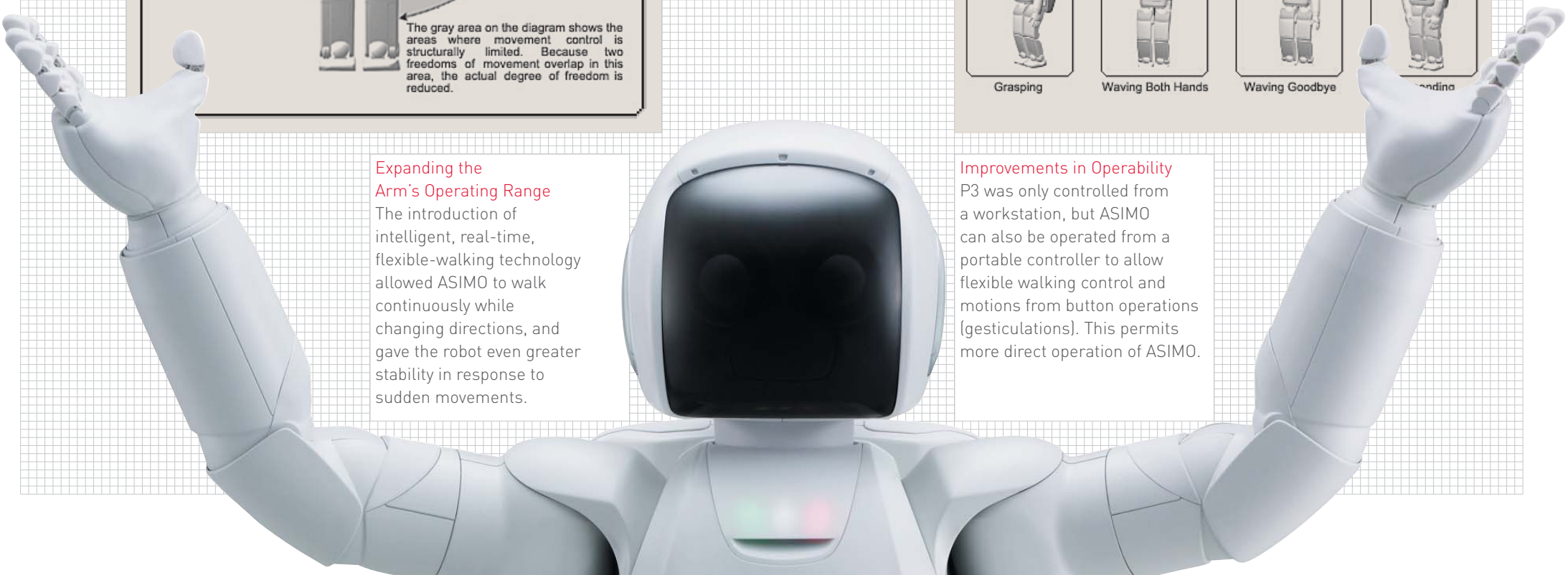


Expanding the Arm's Operating Range

The introduction of intelligent, real-time, flexible-walking technology allowed ASIMO to walk continuously while changing directions, and gave the robot even greater stability in response to sudden movements.

Improvements in Operability

P3 was only controlled from a workstation, but ASIMO can also be operated from a portable controller to allow flexible walking control and motions from button operations (gesticulations). This permits more direct operation of ASIMO.



Intelligence

In 2002, Honda added intelligence technology to ASIMO which is capable of interpreting the postures and gestures of humans and moving independently in response. ASIMO's ability to interact with humans has advanced significantly - it can greet approaching people, follow them, move in the direction they indicate, and even recognize their faces and address them by name. Further, utilising networks such as the Internet, ASIMO can provide information while executing tasks such as reception duties. ASIMO is the world's first humanoid robot to exhibit such a broad range of intelligent capabilities.

ADVANCED COMMUNICATION ABILITY THANKS TO RECOGNITION TECHNOLOGY

Recognition of moving objects

Using the visual information captured by the camera mounted in its head, ASIMO can detect the movements of multiple objects, assessing distance and direction. Specifically, ASIMO can:

- follow the movements of people with its camera;
- follow a person;
- greet a person when he or she approaches.

Recognition of postures and gestures

Based on visual information, ASIMO can interpret the positioning and movement of a hand, recognizing postures and gestures. Thus ASIMO can react not only to voice commands, but also to the natural movements of human beings.
For example, ASIMO can:

- recognise an indicated location and move to that location (posture recognition);
- shake a person's hand when a handshake is offered (posture recognition);
- respond to a wave by waving back (gesture recognition).

Environment recognition

ASIMO is able to assess its immediate environment, recognizing the position of obstacles and avoiding them to prevent collisions.
Specifically, ASIMO can:

- stop and start to avoid a human being or other moving object which suddenly appears in its path;
- recognise immobile objects in its path and move around them.

Distinguishing sounds

ASIMO's ability to identify the source of sounds has been improved, and it can distinguish between voices and other sounds.
For example, ASIMO can:

- recognise when its name is called, and turn to face the source of the sound;
- look at the face of the person speaking, and respond;
- recognise sudden, unusual sounds, such as that of a falling object or a collision, and face in that direction.

Face recognition

ASIMO has the ability to recognise faces, even when ASIMO or the human being is moving.
For example, ASIMO can:

- recognise the faces of people which have been pre-registered, addressing them by name, communicating messages to them, and guiding them;
- recognise approximately ten different people.

NETWORK INTEGRATION

Integration with user's network system

ASIMO can:

- execute functions appropriately based on the user's customer data;
- greet visitors, informing personnel of the visitor's arrival by transmitting messages and pictures of the visitor's face;
- guide visitors to a predetermined location, etc.

Internet connectivity

Accessing information via the Internet, ASIMO can become a provider of news and weather updates, for example, ready to answer people's questions, etc.

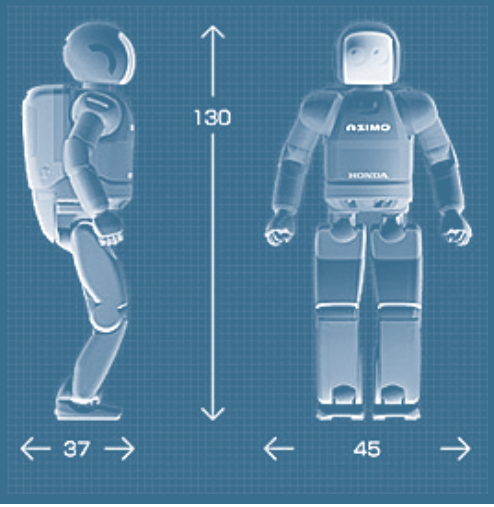
ASIMO v2

New ASIMO

The new ASIMO v2 debuted in late 2005 and has made great leaps forward from its predecessor. In fact, the new ASIMO can walk along with you (holding your hand if you wish), and features advanced mobility, to the extent that ASIMO can now move carts and other objects around at will. And, with a newly developed total control system that controls all of ASIMO's functions, ASIMO can autonomously act as a receptionist, or even deliver drinks on a tray. The new ASIMO is also more agile than before, being able to run at 6km/h, and even turn whilst running.

KEY SPECIFICATIONS

	Asimo v1	Asimo v2
Running speed	n/a	6.0 km/h
Walking speed	1.6 km/h	2.7 km/h
Height	120 cm	130 cm
Width	45 cm	45 cm
Depth	44 cm	37 cm
Weight	52 kg	54 kg
Continuous operating time	30 minutes	40 minutes
Operating degrees of freedom:		
- Head	2	3
- Arm	5x2 - 10	7x2 - 14
- Hand	1x2 - 2	2x2 - 4
- Torso	0	1
- Leg	6x2 - 12	6x2 - 12
- TOTAL	**26**	**34**

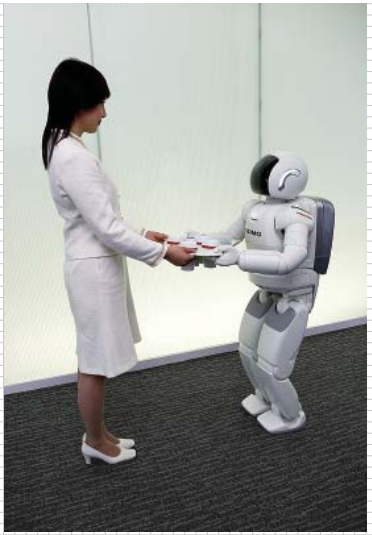


ASIMO v2 debuted in late 2005 and has made great leaps forward from its predecessor.

MAJOR NEW FUNCTIONS

Receptionist Tasks

ASIMO is now capable of performing tasks as a receptionist or information guide automatically in concert with the movement of people. ASIMO now has the ability to recognize the surrounding environment through visual sensors, floor surface sensor, ultrasonic sensor, and by an IC Tele-interaction Communication Card, developed independently by Honda, held by the person with whom ASIMO will interact. Head-mounted eye camera and force (kinesthetic) sensor-equipped wrists allow ASIMO to give and receive an object such as a tray in a timely manner, or even to hold the hand of a person and move in sync.



Carrying Objects

ASIMO is now capable of handling a cart freely while maintaining an appropriate distance from the cart by adjusting the force of its right and left arms to push a cart using the force (kinesthetic) sensor on its wrists. Even when the movement of the cart is disturbed, ASIMO can continue maneuvering by taking flexible actions such as slowing down or changing directions.

THE FUTURE

As development continues on ASIMO, today Honda demonstrates ASIMO around the world to encourage and inspire young students to study the sciences. And in the future, ASIMO may serve as another set of eyes, ears, hands and legs for all kinds of people in need. Someday ASIMO might help with important tasks like assisting the elderly or a person confined to a bed or a wheelchair. ASIMO might also perform certain tasks that are dangerous to humans, such as fighting fires or cleaning up toxic spills.

HONDA

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