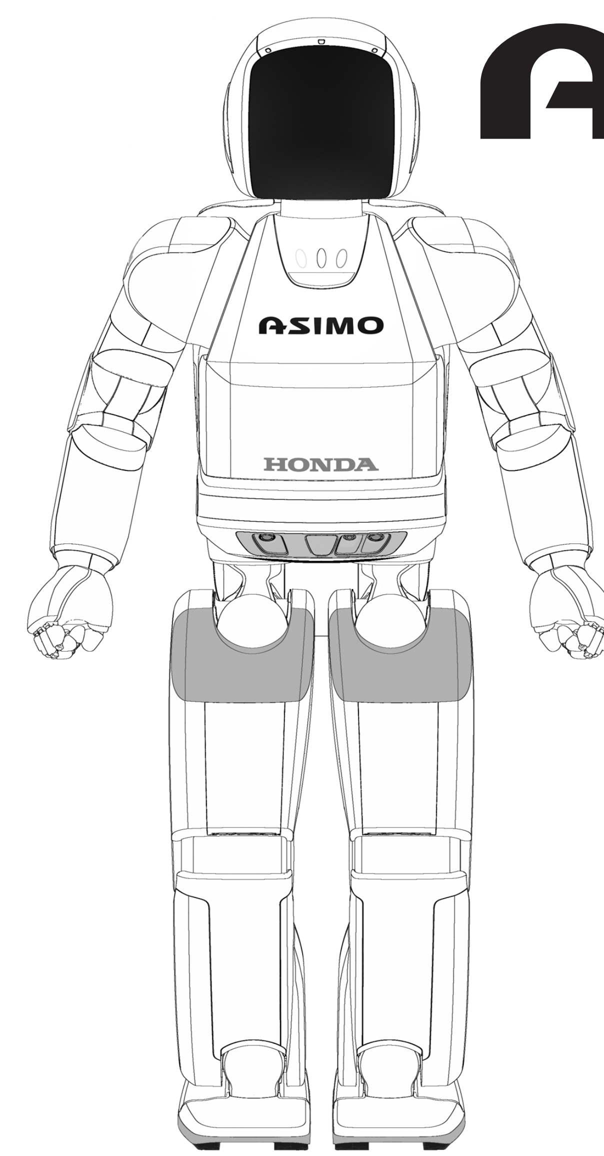
HONDA

ASIMO



Technical Information
September 2007

Honda Motor Co., Ltd.
Public Relations Division

The Honda HUMANOID ROBOT

Contents

ASIMO

By helping people,

and becoming their partners,

Honda robots are opening the door

to the 21st Century.

Prologue - Robot Development

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.

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.

The Concepts 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 maneuver 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.

Robot Development Process

*The "E" in Models E0~E6 stands for ÒExperimental Model."
*The "P" in Models P1~P3 stands for "Prototype Model."

Start of R&D

1986

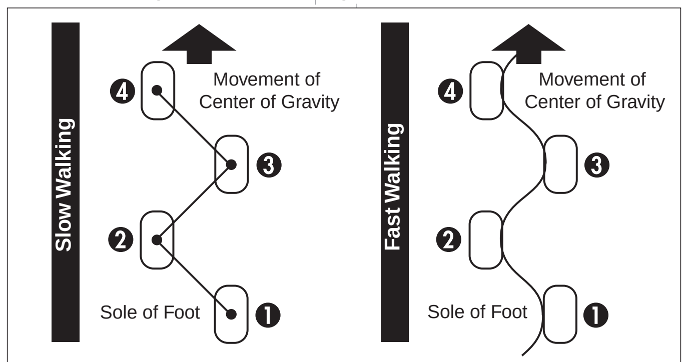
Examining the Principles of Two-Legged Locomotion

E0

First, a two-legged robot was made to walk.

Walking by putting one leg before the other was successfully achieved. However, taking nearly five seconds between steps, it walked very slowly in a straight line.

Slow Walking & Fast Walking



- During slow walking, the body's center of gravity remains always centered on the soles of the feet.
- When body movement is used for smooth, fast walking, the center of gravity is not always on the soles of the feet.

To increase walking speed, or to allow walking on uneven surfaces or slopes, fast walking must be realized.

1987 - 1991

Realizing Rapid Two-Legged Walking

E1-E2-E3

To achieve a fast walking pace, it was necessary to study how human beings walk.

Human walking was thoroughly researched and analyzed. In addition to human walking, animal walking and other forms of walking were also studied, and the movement and location of the joints needed for walking were also researched.
Based on data derived from human walking, a fast walking program was created, input into the robot and experiments were begun.

The E2 robot achieved fast walking at a speed of 1.2 km/h on flat surfaces.

The next step was to realize fast, stable walking in the human living environment, especially on uneven surfaces, slopes and steps, without falling down.

TECHNOLOGY 1

Research On Human Walking

1991 - 1993

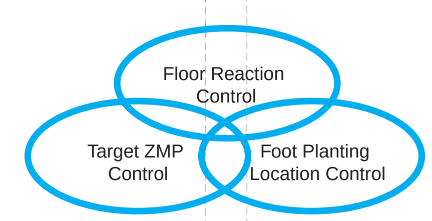
Completing the Basic Functions of Two-Legged Walking

E4-E5-E6

Establishing Technology for Stable Walking

Honda investigated techniques for stabilizing walking, and developed three control techniques.

The 3 Posture Controls Needed for Stable Walking



The walking mechanism was established with the E5. Honda's E5 robot achieved stable, two-legged walking, even on steps or sloping surfaces.

The next step was to attach the legs to a body and create a humanoid robot.

TECHNOLOGY 2

Achieving Stable Walking

1993- 1997

Research on Completely Independent Humanoid Robots

P1-P2-P3

Advances in Humanoid Robots

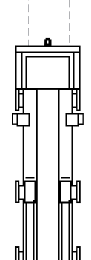
P1 Humanoid Robot Model #1
Height: 1,915mm Weight 175kg
The robot can turn external electrical and computer switches on and off, grab doorknobs, and pick up and carry things. Research was also carried out on coordination between arm and leg movements.

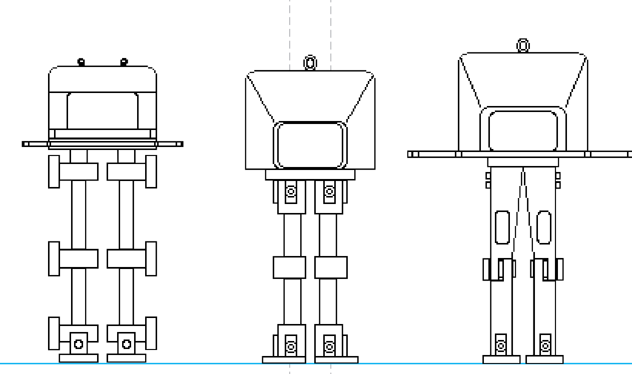
P2 The world's first self-regulating, two-legged humanoid walking robot debuted in December, 1996.
Height: 1,820mm Weight: 210kg
Using wireless techniques, the torso contained a computer, motor drives, battery, wireless radio and other necessary devices, all of which were built in. Independent walking, walking up and down stairs, cart pushing and other operations were achieved without wires, allowing independent operation.

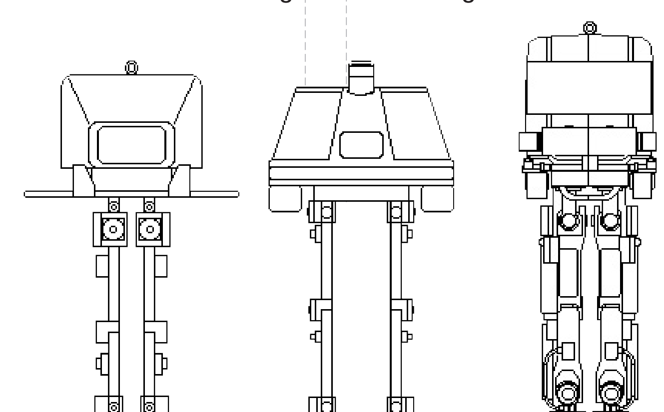
P3 The first completely independent, two-legged humanoid walking robot was completed in September, 1997.
Height: 1,600mm Weight: 130kg
Size and weight were reduced by changing component materials and by decentralizing the control system. Its smaller size is better suited for use in the human environment.

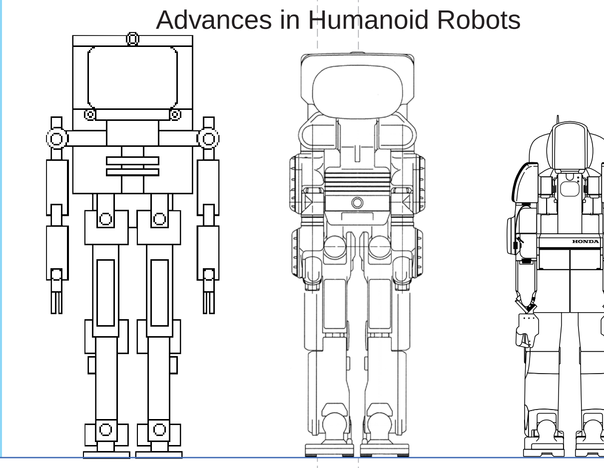
TECHNOLOGY 3

Advances in Humanoid Robots


E0


E1 E2 E3


E4 E5 E6


P1 P2 P3

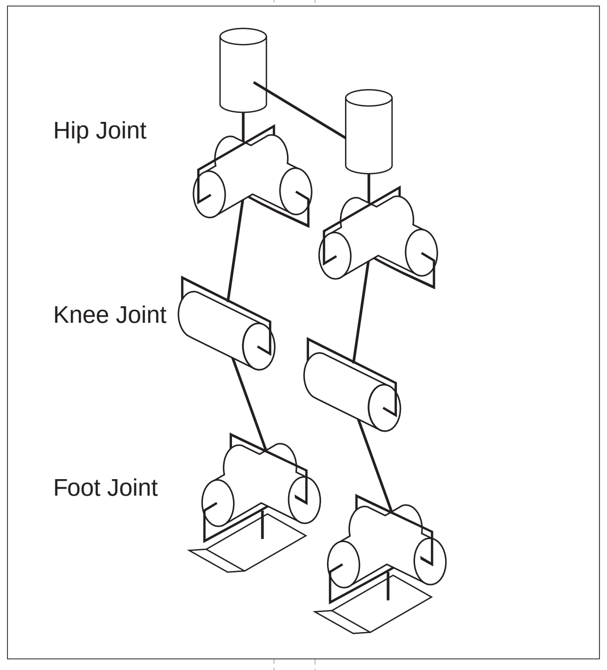
TECHNOLOGY 1 Research On Human Walking

The robot's walk is modeled on a human being's

In studying the fundamental principles of two-legged walking, Honda researched both human and other forms of walking, performed numerous experiments and collected an immense amount of data. Based on this research, Honda established fast-walking technology just like a human's.

1 Leg Joint Placement

The human skeleton was used for reference when locating the leg joints.
Regarding the toes' influence on the walking function, it became clear that the location where the toes were attached and the where the heel joint was positioned were very important in determining how the robot's weight was supported.
Contact sensations from the surface come from the foot joints. Because the foot joints turn from front to back, and left to right, there is stability in the longitudinal direction during normal walking, and feel for surface variations in the lateral direction is enhanced when traversing a slope at an angle.
The knee joint and hip joint are needed for climbing and descending stairs, as well as for straddling.
The robot system was given many joint functions such as hip joints, knee joints and foot joints.



2 Range of Joint Movement

Regarding the range of joint movement during walking, research was carried out on human walking on flat ground and on stairs. Joint movements were measured, and this determined the range of movement for each joint.

3 Leg Dimensions, Weight & Center of Gravity Location

To determine the location of each leg's center of gravity, the human body's center of gravity was used for reference.

4 Torque Exerted on Leg Joints While Walking

To determine the ideal torque exerted on the joints while walking, the vectors at the joints during human walking and during occasional floor reaction were measured.

5 Sensors For Walking

Human beings have the following three senses of balance:

- Speed sensed by the otolith of the inner ear
- Angular speed sensed by the semicircular canals
- Deep sensations from the muscles and skin, which sense the operating angle of the joints, angular speed, muscle power, pressure on the soles of the feet, and skin sensations

To "comprehend" the foot's movement during walking, the robot system is equipped with a joint angle sensor, a 6-axis force sensor, and a speed sensor and gyroscope to determine position.

6 Impact Force During Walking

Human beings have structural elements such as soft skin and heels, as well as arch structures consisting of toe joints. These combine with moveable parts which absorb bending impacts to the joints when the foot contacts the ground, softening the impact force.
Experiments and analyses of human walking have shown that when walking speed increases, floor reaction increases even when the impact reduction functions are at work. At walking speeds of 2~4km/h, the impact is 1.2~1.4 times body weight; at 8km/h, the load increases to 1.8 times body weight.
With the robot, impact-absorbing material on the soles of the feet and compliance controls are used to reduce the impact.

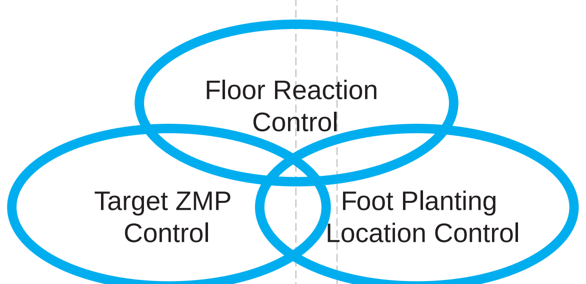
TECHNOLOGY 2 Achieving Stable Walking

To achieve stable walking...

Issues to be address in order to achieve stable walking...

¥Not falling down even when the floor is uneven. ¥Not falling down even when pushed.
¥Being able to walk stable on stairs or slopes.

A Posture Controls to Achieve Stable Walking



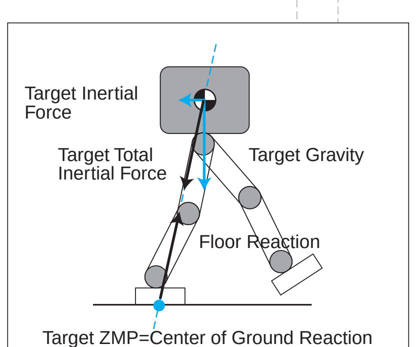
Floor Reaction Control Firm standing control of the soles of the feet while absorbing floor unevenness.

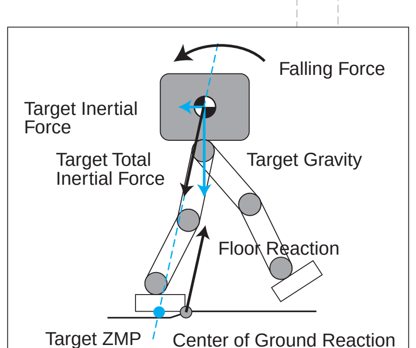
Target ZMP Control Control to maintain position by accelerating the upper torso in the direction in which it threatens to fall when the soles of the feet cannot stand firmly.

Foot Planting Location Control Control using side steps to adjust for irregularities in the upper torso caused by target ZMP control.

* ZMP = Zero Moment Point: The point when total inertial force is 0.

B 3 Position-Control Arrangements

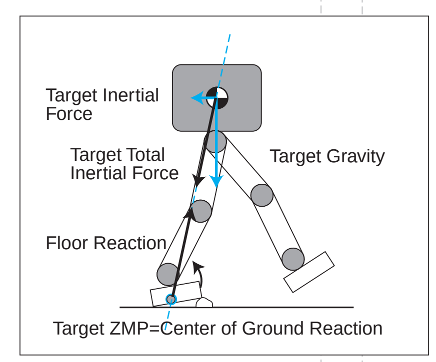




When the robot is walking, it is influenced by inertial forces caused by the earth's gravity and the acceleration and deceleration of walking.These combined forces are called the total inertial force. When the robot's foot contacts the ground it is influenced by a reaction from the ground called the floor reaction force.

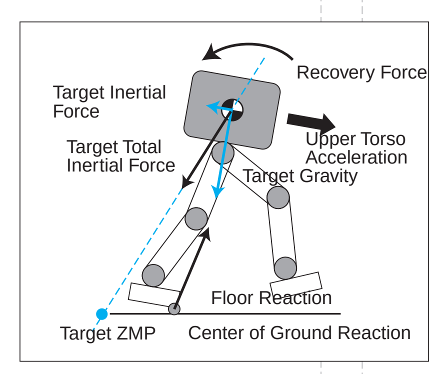
The intersection of the floor and the axis of the total inertial force has a total inertial force moment of 0, so it is called the Zero Moment Point.The point where the floor reaction force operates is called the floor reaction point.
Basically, an ideal walking pattern is created by the computer and the robot's joints are moved accordingly. The total inertial force of the ideal walking pattern is called the target total inertial force, and the ZMP of the ideal walking pattern is called the target ZMP.
When the robot is maintaining perfect balance while walking, the axes of the target total inertial force and the actual floor reaction are the same. Accordingly, the target ZMP and the center of ground reaction are the same.
When the robot walks across uneven ground, the axes of the target total inertial force and the actual floor reaction force are out of alignment, balance is lost and falling force is generated.
This falling force is comparable to the misalignment of the target ZMP and the center of ground reaction. In short, the misalignment between the target ZMP and the center of ground reaction is the main cause of loss of balance.

When the Honda robot loses its balance and threatens to fall, the following three control systems operate to prevent the fall and allow continued walking.



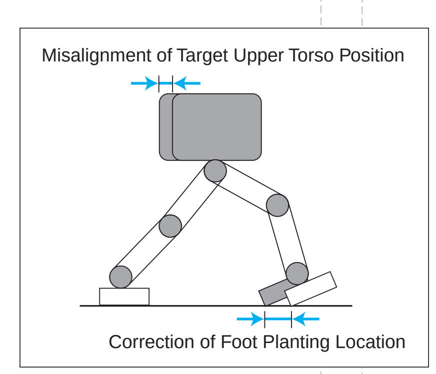
Floor Reaction Control

The floor reaction control absorbs irregularities in the floor and controls the placement of the soles of the feet when falling is imminent. For example, if the tip of the robot's toe steps on a rock, the actual center of ground reaction shifts to the tip of the toe. The floor reaction control then causes the toe to rise slightly, returning the center of ground reaction to the target ZMP.
Another example would be if something caused the robot to lean forward, the tips of the toes would be lowered, placing more pressure on them and the actual floor reaction action point would be shifted forward, generating a position recovery force. However, because the center of ground reaction cannot exceed the scope of the foot sole contact patch there is a limit to the position recovery force, and if the robot leans too far forward it will fall. forward it will fall.



Target ZMP Control

If the robot leans too far over, the target ZMP control operates to prevent it from falling.As stated above, misalignment of the target ZMP and the actual floor reaction action point generates a falling force. However, the target ZMP control maintains the robot's stability.For example, in the diagram to the left, if the robot starts to fall forward, its walking speed is accelerated forward from the ideal walking pattern. As a result, the target ZMP is shifted rearward from the actual floor reaction action point and a rearward falling force is created which corrects the robot's position.



Foot Planting Location Control

When the target ZMP control operates, the target position of the upper torso shifts in the direction of acceleration. When the next step is taken in the ideal step length, the feet will fall behind the torso. The stepping placement control idealizes the stride to ensure the ideal relationship between torso speed and length of stride is maintained.

TECHNOLOGY 3 Advances in Humanoid Robots

Creating a Humanoid Robot

After establishing the two-legged walking technology, work was begun on combining an upper torso with the legs and developing humanoid robot technology.Studies were carried out to determine what a humanoid robot should be like to function in society and in a human living environment, and a prototype model of almost human size was completed.

A Basic Structure

Movement by Two-Legged Walking Mechanism

+

Work by Two-Armed Mechanism

To work in harmony with people and for ease of operation, it was decided that the robot should have two arms.

B Basic Functions

Target Point Movement
From the erect position, a camera is used to recognize two markers placed on the floor or other spots. After the robot estimates its present location and direction, it designates a target point. It then calculates the method giving the minimum amount of walking required to move from its present location to the target point. The gyroscope is used for inertial navigation as it moves to the target point, correcting for irregularities caused by slippage, etc.

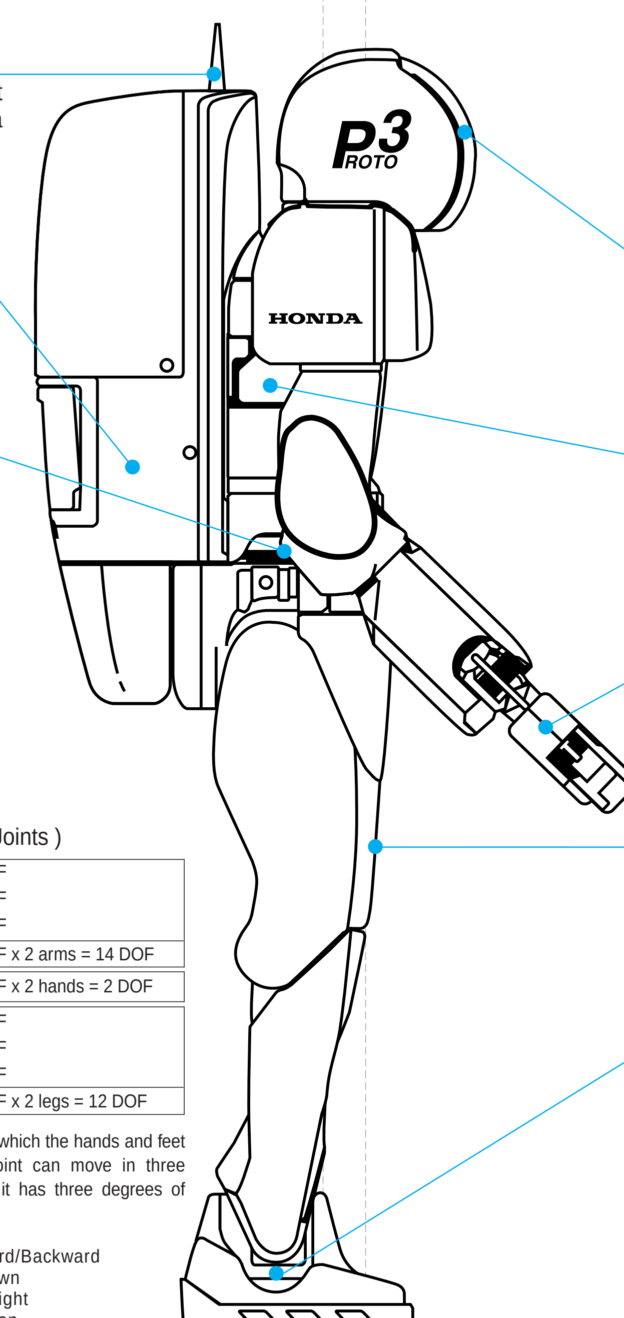
Climbing/Descending Stairs
A 6-axis force sensor is used to measure steps, so the robot can negotiate even long stairways continuously without missteps.

Cart Pushing
The robot can push carts at a set speed, but if the cart encounters some kind of resistance the robot shortens its stride in response to avoid excessive pushing.

Passing Through Doorways
The robot can open and close doors while passing through doorways. As in cart pushing, its steps are regulated in response to the door's opening/closing condition.

Carrying Things
Each arm can carry up to 2kg while walking.

Working Via Remote Operation
The robot can tighten bolts and perform other tasks with the master arm while sensing hand operating pressure.



Antenna
Data is transmitted between the robot and the operating computer via wireless communication.

Battery
The nickel-zinc battery allows approximately 25 minutes of operation.

Gyroscope & Acceleration Sensor
These sense body lean and acceleration.

Height	160cm
Weight	130kg
Walking Speed	2km/h(Max.)

Camera
Images from the camera show the operator how to direct the robot and detect the target location.

Body
The body is made of a very lightweight and tough magnesium alloy.

6-Axis Force Sensor
This senses the direction and amount of force on the hand.

Actuator
A brushless DC servomotor and harmonic drive speed reducer perform the functions of human muscles.

6-Axis Force Sensor
Images from the camera show the operator how to direct the robot and detect the target location.

Compact & Lightweight
Light weight and compactness were achieved using lightweight materials and decentralizing the controls.

Degrees of Freedom (For Human Joints)

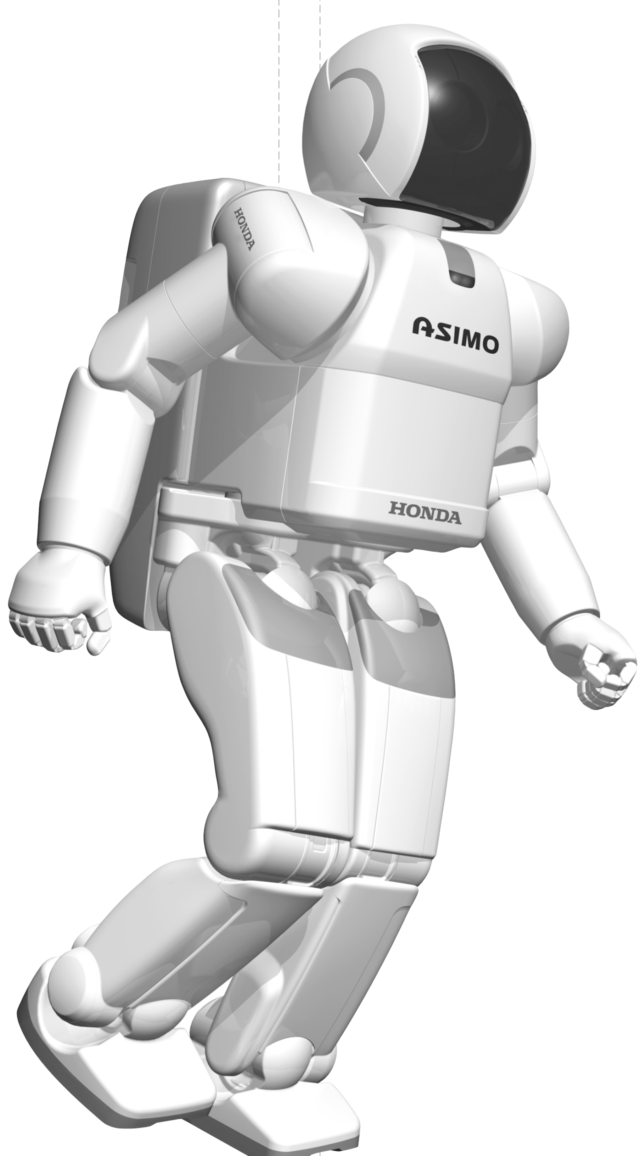
Arm	Shoulder Joint (F/B,U/D,RT)*1	3 DOF
	Elbow joint (F/B)	1 DOF
	Wrist joint (F/B,L/R,RT)	3 DOF
		7 DOF x 2 arms = 14 DOF
Hand	Grasping movement	1 DOF x 2 hands = 2 DOF
Foot	Pelvis joint (F/B,L/R,RT)	3 DOF
	Knee joint: (F/B)	1 DOF
	Ankle joint: (F/B,L/R)	2 DOF
		6 DOF x 2 legs = 12 DOF

Degrees of freedom (DOF) are the directions in which the hands and feet can move. For example, the human wrist joint can move in three directions: up, down, left, right, and twist, so it has three degrees of freedom.

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

ASIMO Is Born!

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 on November 20, 2000.



ASIMO

Naming ASIMO

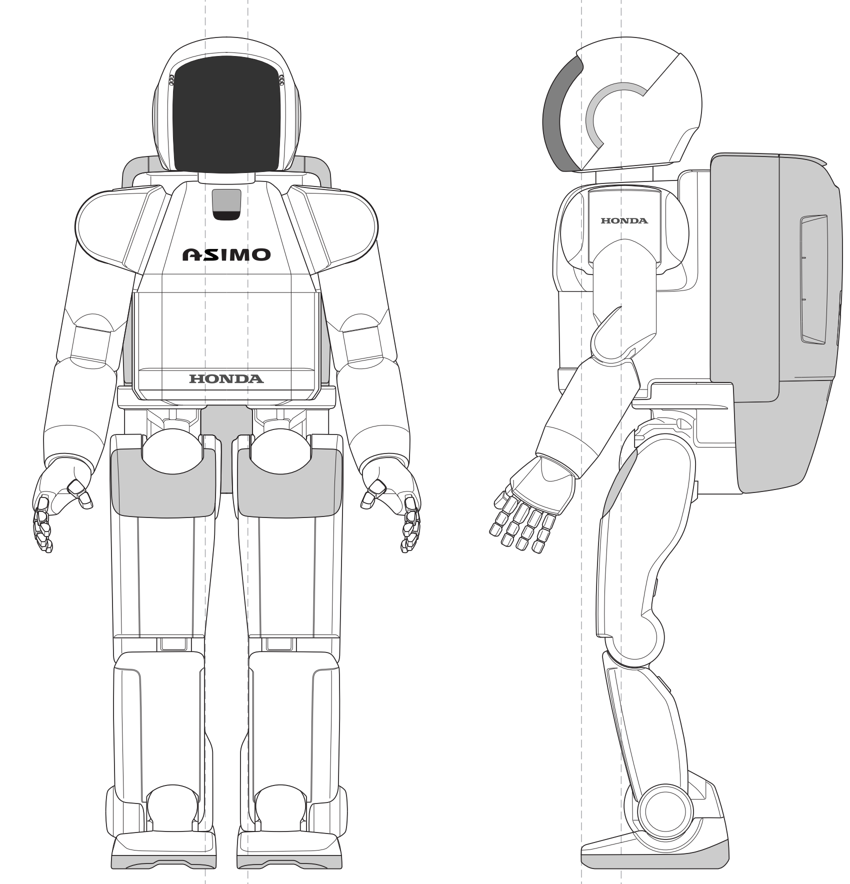
Advanced --- New Era
Step in --- Stepping
Innovative --- Innovation
Mobility --- Mobility

ASIMO stands for Advanced Step in Innovative Mobility.
It means advanced innovative mobility for a new era.

ASIMO Features

- Compact & Lightweight
- More Advanced Walking Technology
- Wider Arm Operating Parameters
- Easy to Operate
- Friendly Design

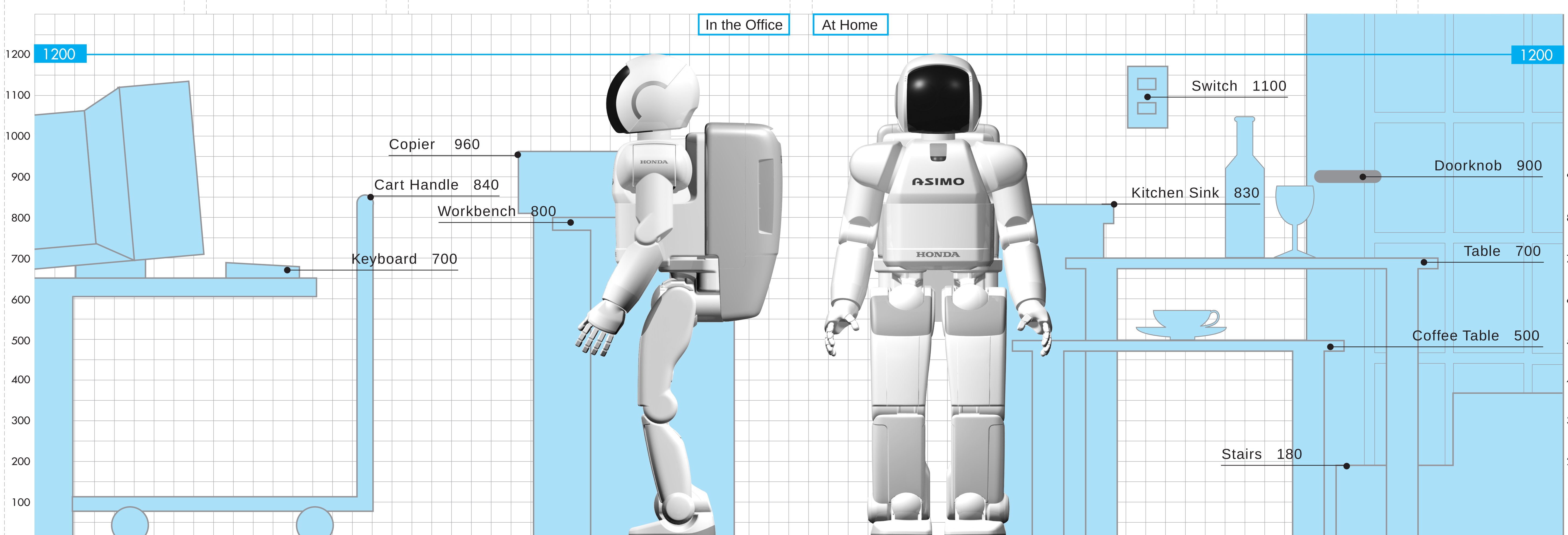
ASIMO was conceived to function in an actual human living environment in the near future.
It is easy to operate, has a convenient size and weight and can move freely within the human living environment, all with a people-friendly design.



The People-Friendly Robot.

Small, Useful Size

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).

Smoother and More Stable Walking

The introduction of intelligent, real-time, flexible-walking i-WALK 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 strides (time per step) were limited to only a few variations.

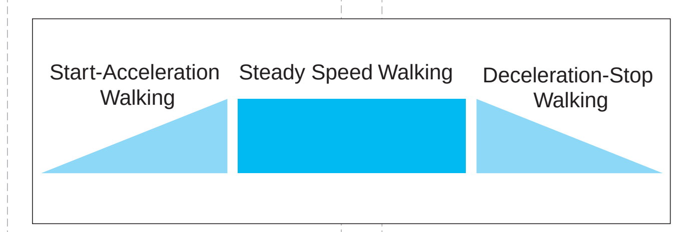
Because each walking pattern has a different stride(time per step), the robot could not change its stride(time per step) flexibly.

Creating Earlier Walking Patterns

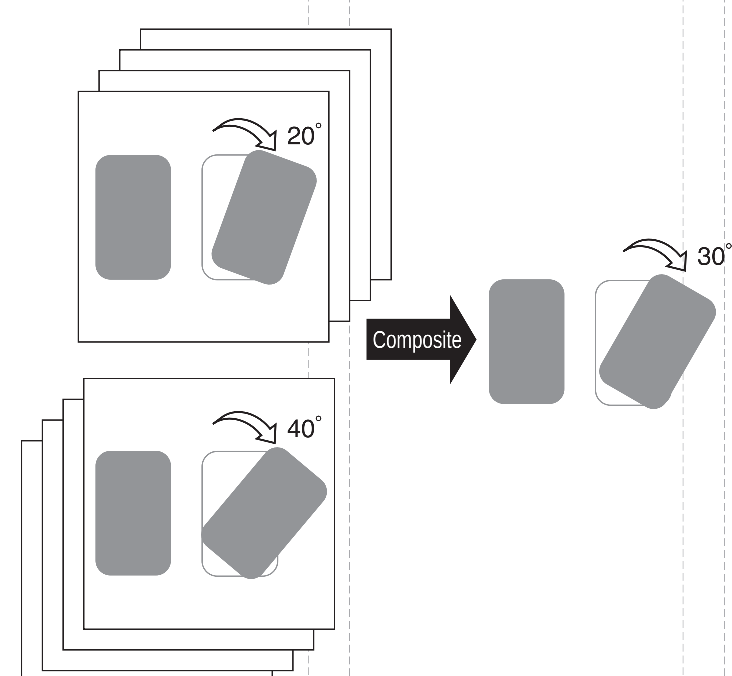
Earlier walking technology allowed roughly two different walking patterns.

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.

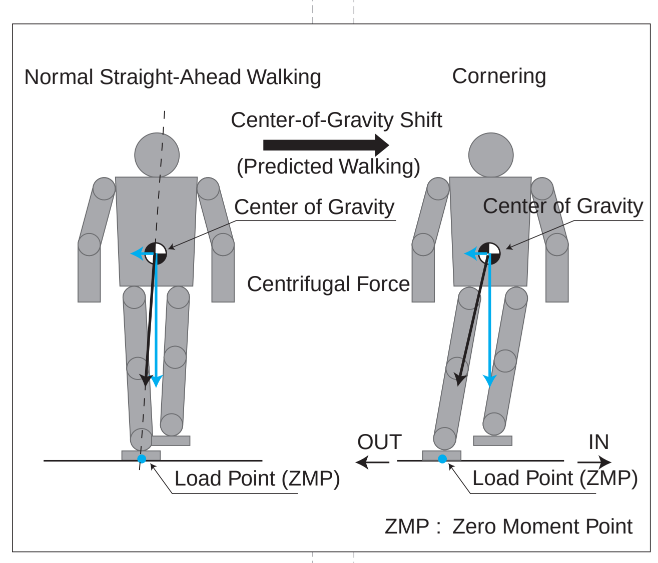
For example, the P3 robot combined 20û and 40û walking patterns to turn at 30û.

Intelligent Real-Time Flexible Walking = i-WALK

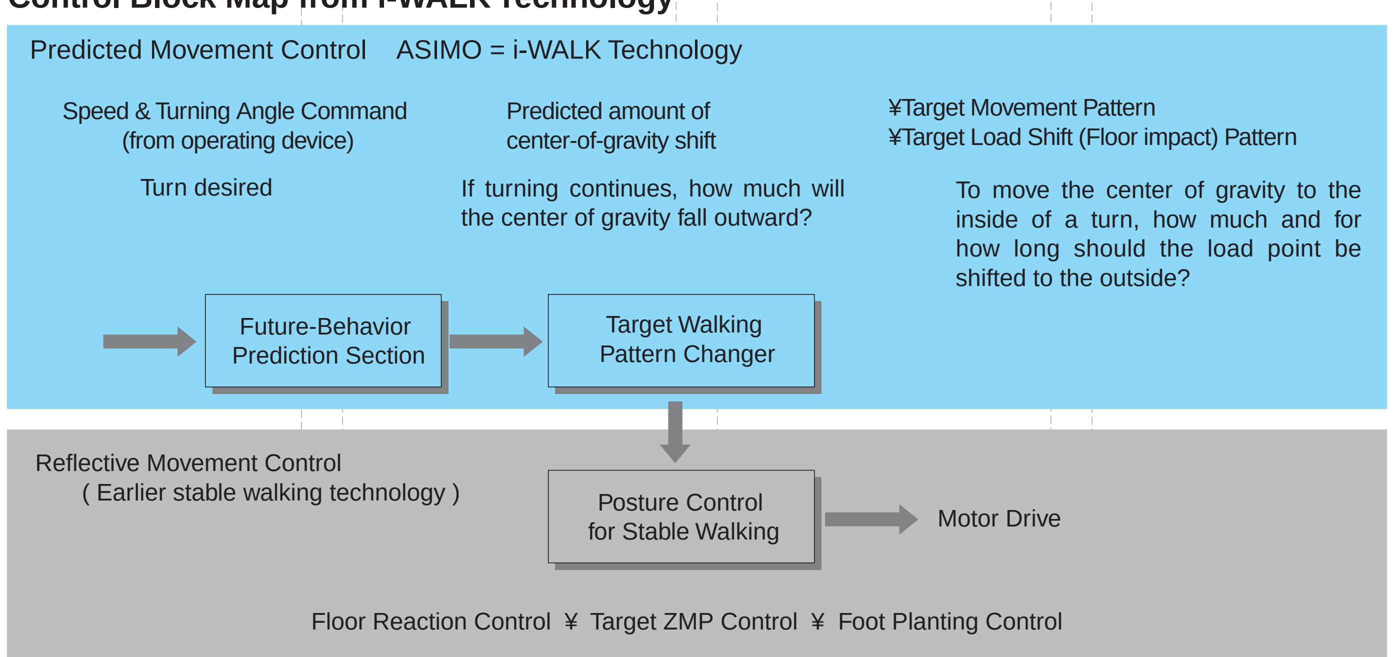
i-WALK technology features a predicted movement control added to the earlier walking control technology. This new two-legged walking technology permits more flexible walking. As a result, **ASIMO** now walks more smoothly and more naturally.

Creating Prediction Movement Control

When human beings walk straight ahead and start to turn a corner, before commencing the turn they shift their center of gravity toward the inside of the turn.
Thanks to i-WALK technology, ASIMO can predict its next movement in real time and shift its center of gravity in anticipation.



Control Block Map from i-WALK Technology



Intelligent, Real-Time, Flexible Walking Achieved!

1 Continuous movement is possible without pauses.

Straight Ahead → Turning → Straight Ahead

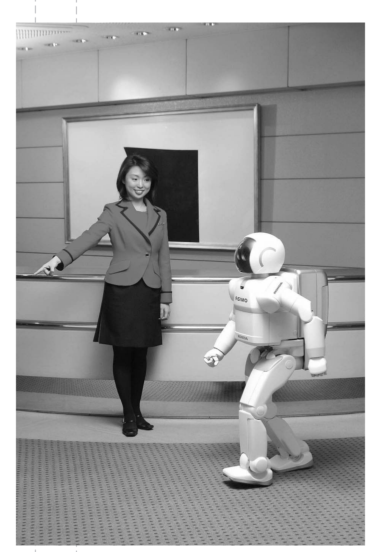
Because continuous flexible walking is possible, ASIMO can move and walk rapidly and smoothly at all times.

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

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 freely changed, ASIMO's movements are much more natural.

ASIMO Featuring Intelligence Technol ogy

December 5, 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, utilizing 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.



Movement in response to a gesture (posture recognition)

Advanced communication ability thanks to recognition technology

1 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.

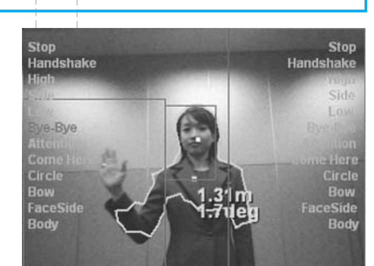
Recognition of the distance and direction of movement of multiple objects

2 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:
: recognize 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).

Movement to an indicated location



Recognition of hand movements such as the waving of a hand

3 Environment recognition

Using the visual information, 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;
: recognize immobile objects in its path and move around them.

4 Distinguishing sounds

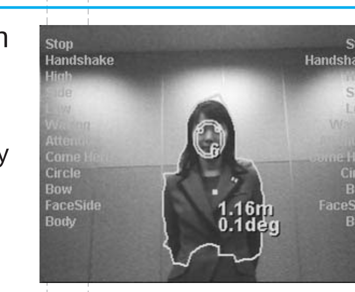
ASIMO's ability to identify the source of sounds has been improved, and it can distinguish between voices and other sounds.

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

5 Face recognition

ASIMO has the ability to recognize faces, even when ASIMO or the human being is moving.

For example, ASIMO can:
: recognize the faces of people which have been pre-registered, addressing them by name, communicating messages to them, and guiding them;
: recognize approximately ten different people.



Distinguish between registered faces.

Network integration

1 Integration with user's network system

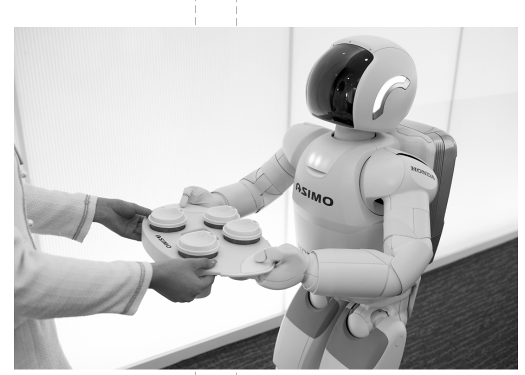
ASIMO can:
: execute functions appropriately based on the user's customer data;
: greet visitors, informing personnel of the visitor's arrival by transmitting messages and pictures of the visitor's face;
: guide visitors to a predetermined location, etc.

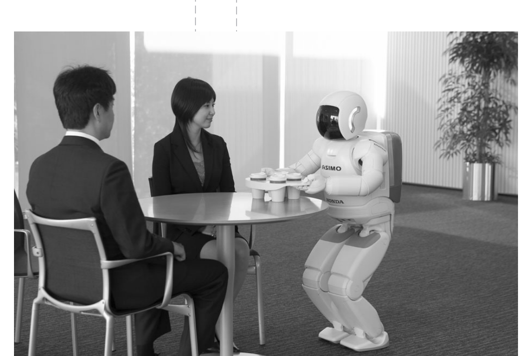
2 Internet connectivity

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

New ASIMO Debut

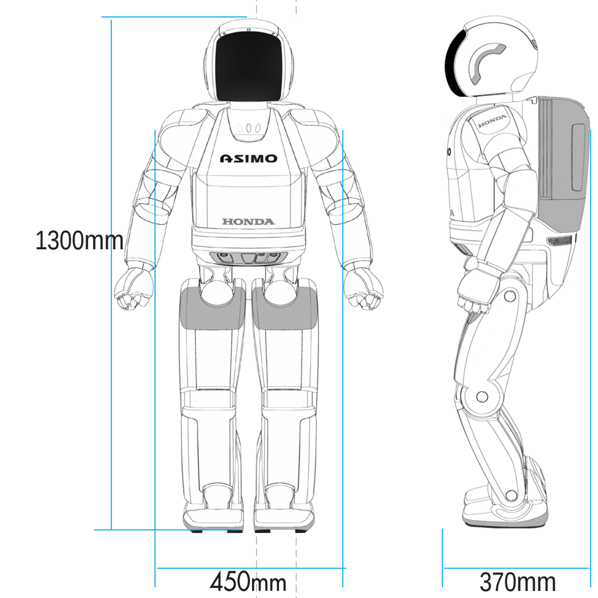
Honda debuted a new ASIMO humanoid robot which features the ability to pursue key tasks in a real-life environment such as an office and an advanced level of physical capabilities. Compared to the previous model, the new ASIMO achieves the enhanced ability to act in sync with people - for example, walking with a person while holding hands. A new function to carry objects using a cart was also added. Further, the development of a "total control system" enables ASIMO to automatically perform the tasks of a receptionist or information guide and carry out delivery service. In addition, the running capability is dramatically improved, with ASIMO now capable of running at a speed of 6km/hour and of running in a circular pattern





Major Advancement of New ASIMO

- **Improved Running Ability**
- **Enhanced Ability to Act in Sync With People**
- **Function to Carry Objects Using Tools**



Total Height	130cm
Weight	54kg
Running Speed (Straight)	6 km/h
Running Speed (Circular Pattern)	5 km/h (2.5m radius)
Walking Speed (Normal)	2.7 km/h
Walking Speed (While Carrying ObjectWith)	1.6 km/h (carrying object weighing 1kg)

Degrees of Freedom (The human joint has one degree of freedom for each range of movement)

Head	Neck joint (U/D, L/R RT)	3 DOF
Arm	Shoulder joints (F/B, U/D, RT)	3 DOF
	Elbow joints (F/B)	1 DOF
	Wrist joints (U/D, L/R, RT)	3 DOF
		7 DOF x 2 arms = 14 DOF
Hands	4 fingers (to grasp objects) / Thumb	2 DOF
		2 DOF x 2 hands = 4 DOF
Hip	RT	1 DOF
Legs	Crotch joint (F/B, L/R, RT)	3 DOF
	Knee joints (F/B)	1 DOF
	Ankle joints (F/B, L/R)	2 DOF
		6 DOF x 2 legs = 12 DOF
TOTAL		34 DOF

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

New Technology in ASIMO

Improved physical capabilities

Further advanced walking function

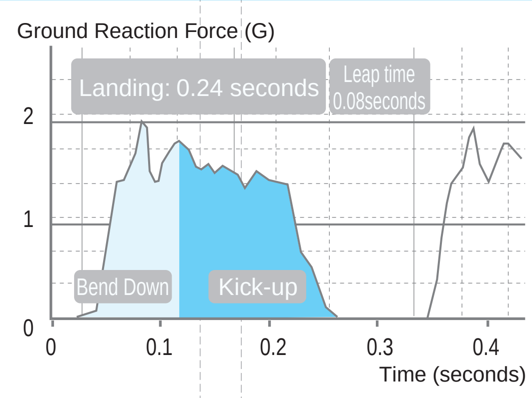
To maintain balance while increasing walking speed and preventing the feet from slipping or rotating in mid-air, we developed new posture control logic that employs active use of the bending and twisting of the upper body, as well as highly responsive hardware. This has enabled ASIMO to run at 6 km/h, and also improved the walking speed to 2.7 km/h.

High Speed Running

There were two challenges in making ASIMO run. One was to obtain an accurate jump function and absorb shock when landing, and the other was to prevent the rotation and slipping as a result of the increased speed.

1 Accurate leap and absorption of the landing impact

In order for ASIMO to run, it had to be able to repeat the movements of pushing off the ground, swinging its legs forward, and landing within a very short time cycle and without any delay, absorbing the instantaneous impact shock of landing. ASIMO is a hardware equipped with a newly developed high-speed processing circuit, highly-responsive and high-power motor drive unit, and light-weight and highly rigid leg structure,



2 Prevention of spinning and slipping

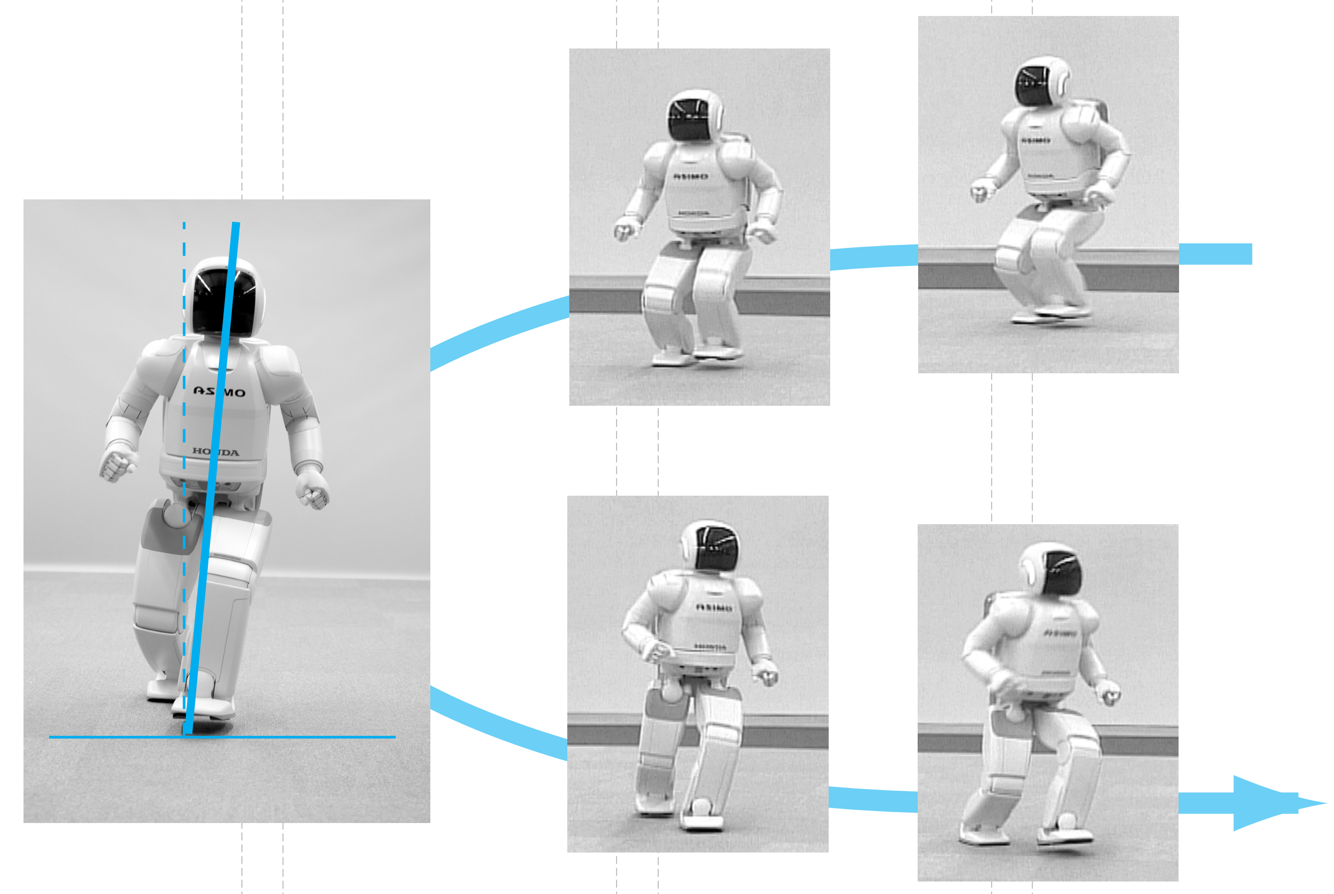
Due to reduced pressure between the bottom of the feet and floor, spinning and slipping are more likely to happen right before the foot leaves the floor and right after the foot lands on the floor. Combining Honda's independently developed theory of bipedal walking control with proactive bending and twisting of the torso, ASIMO achieved stable running while preventing slipping.
When a human runs, the step cycle is 0.2 to 0.4 seconds depending on one's speed, and the leap time, when both feet are off the ground, varies between 0.05 to 0.1 seconds. The step cycle of ASIMO is 0.32 seconds with an leap time of 0.08 seconds, which are equivalent to that of a person jogging.

Speed	Stride	Leap distance*	Leap time
6km/h	525mm	50mm	0.08sec

*Distance ASIMO moves forward while both feet are off the ground

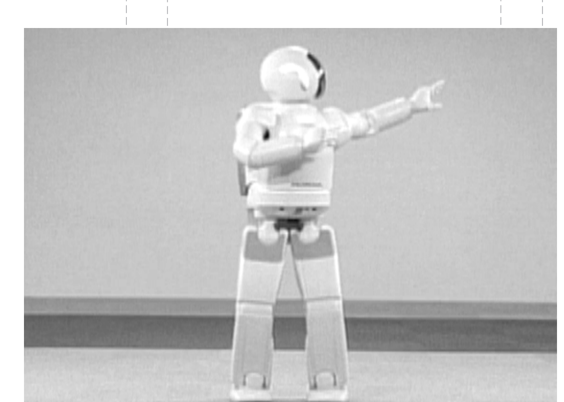
High-Speed Running Turn in a Circular Pattern

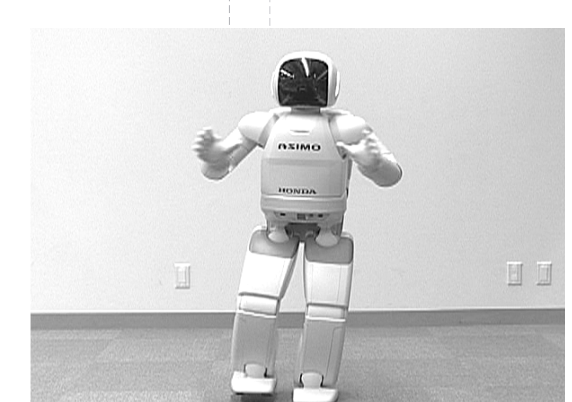
Running in a circular pattern at high speed was achieved by tilting the center of gravity of ASIMO's body inside of the circle to maintain balance with the amount of centrifugal force experienced. The tilting. ASIMO changes its speed according to the radius of the circle and controls its tilted posture.



Coordination of the Entire Body

The development of highly responsive hardware enable ASIMO to freely change speed while it is in motion. This allows ASIMO to conduct flexible and rapid movements using the entire body while maintaining its overall body balance.





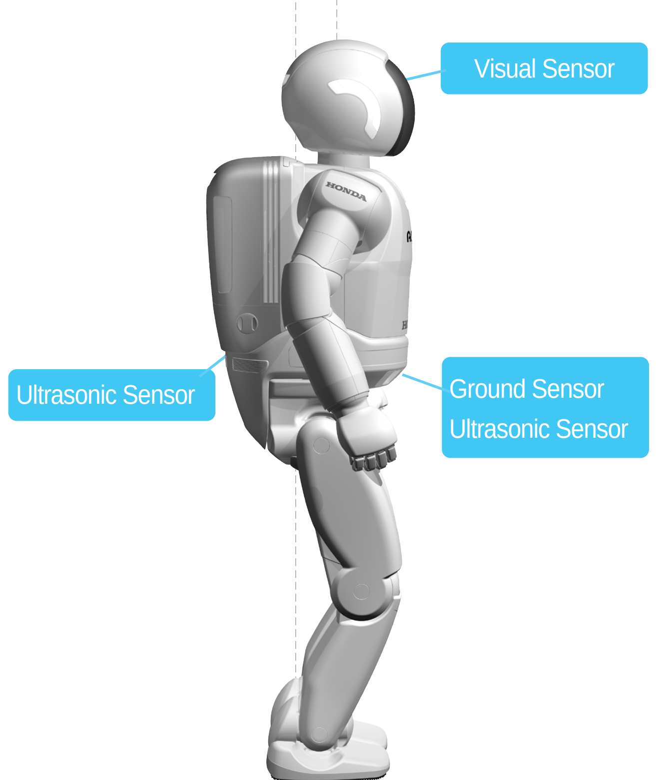
New Technology in ASIMO

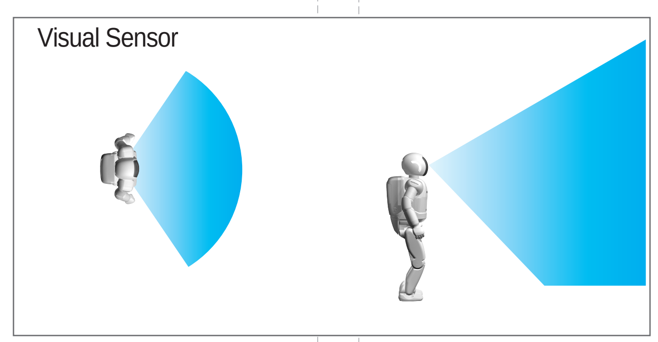
Improving adaptability to changes in environment

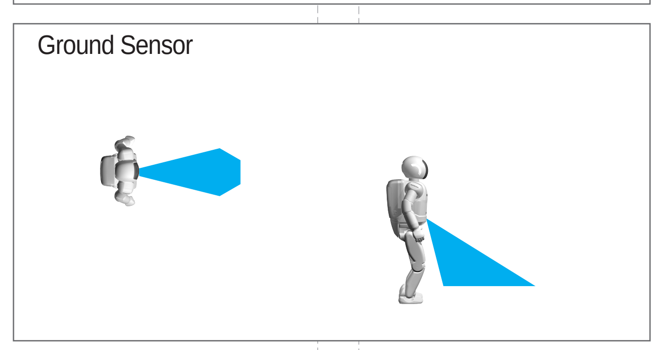
Autonomous Continuous Movement

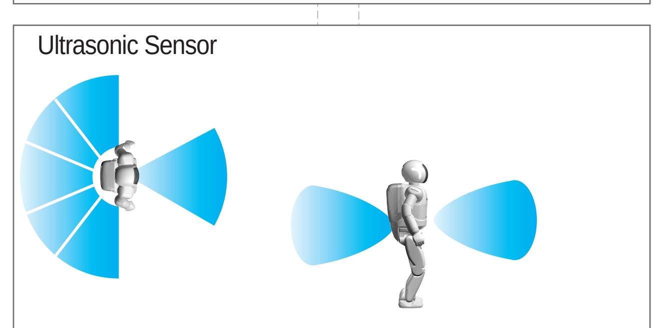
ASIMO can maneuver toward its destination without stopping by comparing any deviation between the input map information and the information obtained about the surrounding area from its floor surface sensor.

ASIMO's Environment Identifying Sensor









Visual Sensor Reads the contour characteristics taken from continuous images of the eye camera (camera with high dynamic range) to distinguish a person, and evaluates the reliability from the contextual data to identify it accurately as a person.

Ground Sensor A sensing system comprised of a laser sensor and an infrared sensor. The laser sensor detects the ground surface and any obstacles two meters from its feet, while the infrared sensor identifies the floor markings by adjusting the shutter speed according to brightness. The differences are corrected according to the robot's map information.

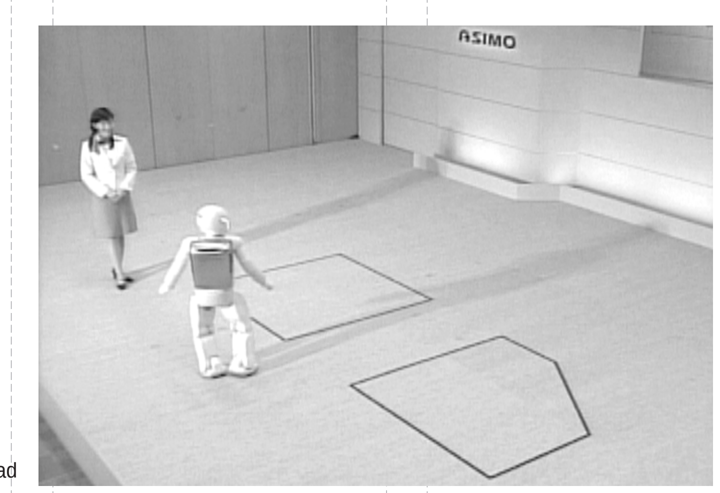
Ultrasonic Sensor The sonic wave sensors detect obstacles three meters ahead, including glass that the visual sensor cannot detect.

Correcting Its Own Position

ASIMO corrects its own positions without stopping based on information obtained from the sensors as it walks and the pre-memorized map information.

Identifying Obstacles

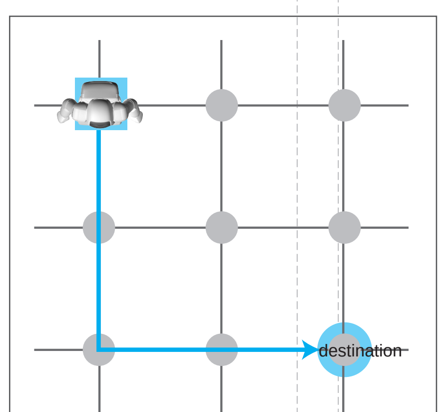
ASIMO selectively use its multiple sensors based on its own judgments, and adjusts the sensitivity of the sensors according to the surrounding circumstances in order to consistently identify obstacles.



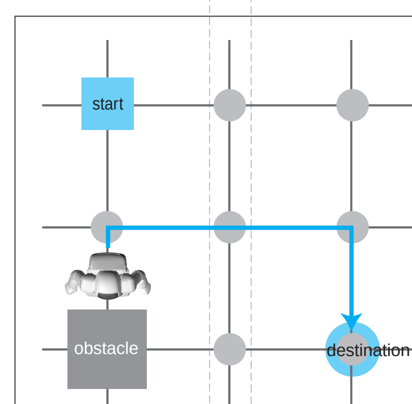
ASIMO, avoiding a person ahead

Automatic Detour Function

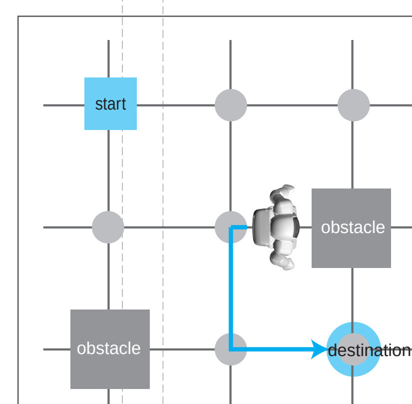
When its ground sensor or the visual sensor on its head identifies an obstacle, it ASIMO selects a different route using its own judgment.



1) Establishes the shortest route from the origin to the destination.



2) Diverts to an alternative route when it finds an obstacle on the shortest route it established.



3) When it finds an obstacle on its alternative route, it diverts to another alternative route.

Improving adaptability to changes in environment

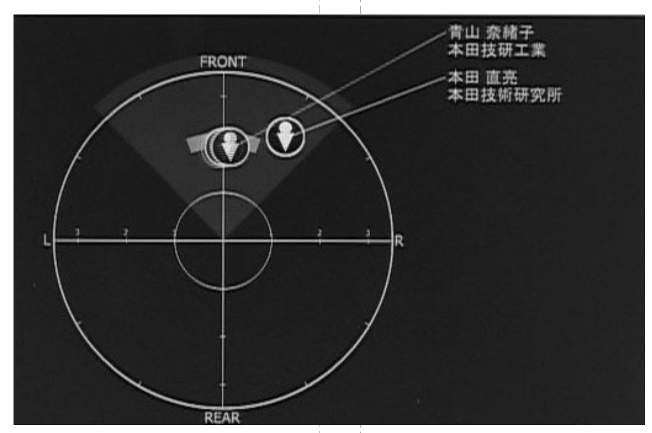
Movement in concert with human motion

Identifying moving subjects

From the characteristics of images obtained from its visual sensor on its head, ASIMO extracts multiple moving subjects, and identifies the distance and direction to those subjects and likelihood of those subjects being people.

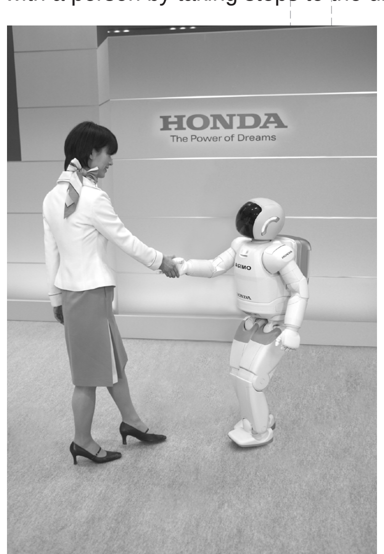
Recognizes people

Based on the information on the IC Communication Card, the position of the person is identified, and ASIMO adjusts its own position to face the person.



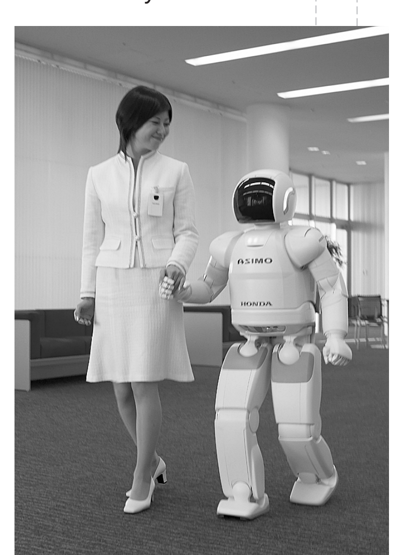
Shakes hands in sync with the person's motion

By detecting people's movments through visual sensors in its head and force (kinesthetic) sensors on its wrists, ASIMO can shake hands in concert with a person's movement. During hand shaking, ASIMO steps backward when the hand is pushed and steps forward when the hand is pulled. ASIMO moves in concert with a person by taking steps to the direction of the force.



Walking hand-in-hand

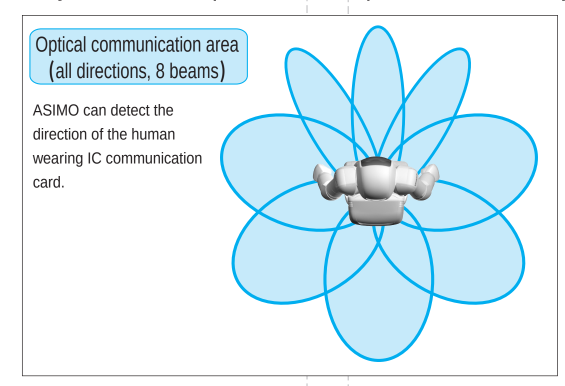
With its force sensors on the wrists, ASIMO detects the strength and direction of the force applied to its hand and adjusts the walking speed and direction. ASIMO takes steps in any direction according to the strength and direction of the force applied to its hand, therefore a person can walk ASIMO in any direction.

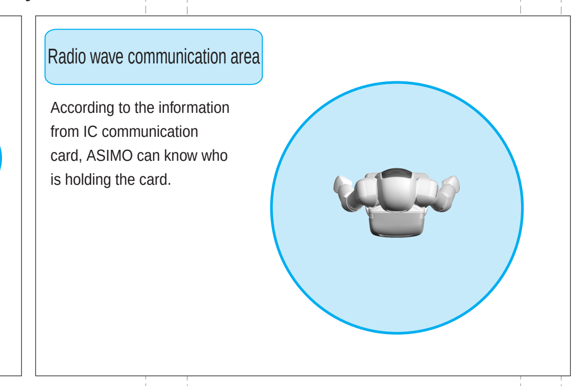


IC Communication Card

In collaboration with Honda's unique IC communication card, an IC tag with optical communication functions, ASIMO autonomously selects and executes its tasks.

Based on customer information pre-registered in the IC communication card, ASIMO identifies the characteristics and relative position of its target person. Even with multiple people around, ASIMO can determine their positions and who they are, and respond to each person individually.



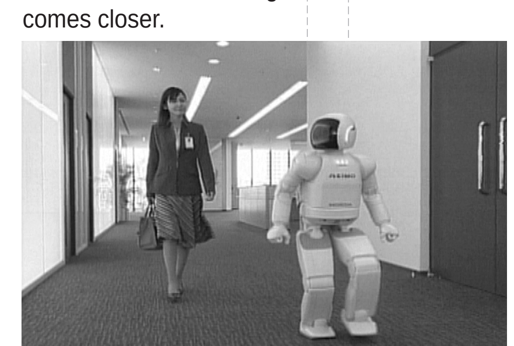


Attending to a person while recognizing the person

Based on the information in the IC Communication card, ASIMO recognizes the individual and attends to the person accordingly.

Attending to a person while measuring the distance to the person

Calculating the relative distance between ASIMO and the person to attend, ASIMO adjusts its walking speed. If the distance becomes too great, ASIMO waits until the person comes closer.

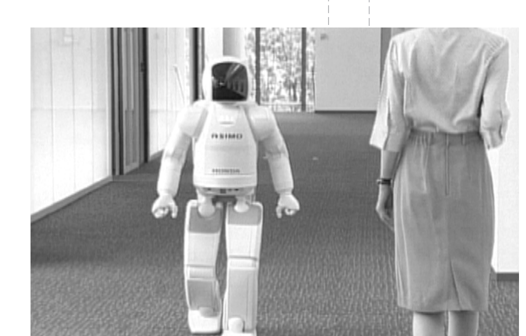


Attending to a person while specifying the position of the person

Based on the information in the IC Communication card ASIMO specifies the position of the person and adjusts its position to attend to them while facing toward that person.

Greeting people as they pass by

When passing a person who carries an IC communication card, ASIMO identifies the card information and greets appropriate for the person.



Carrying objects while using tools

Carrying a tray

ASIMO can deliver objects on a tray to a specified destination.

Handing the tray

By detecting the movement of the person through the eye camera in its head and force sensors on its wrists, ASIMO can move in concert with the person and accurately receive or hand over the tray .

Walking with the tray

While carrying the tray, ASIMO uses its entire body to control the tray to prevent spilling of the objects on the tray. Even if the tray slides and is about to fall, ASIMO's wrist sensors detect the weight differences on its hands and automatically stop walking before it drops the tray.

Putting the tray on a table

When the force sensors on its wrists detect reduction of the load on the wrists as the tray touches the surface of the table, ASIMO sets the tray on the table. By using the entire body to set the tray down, ASIMO can work with tables of different heights.

Handling a cart

It can transport heavy loads by handling a wagon in a flexible manner.

Being able to handle a cart freely, ASIMO is now capable of carrying heavy objects
ASIMO is capable of handling a cart freely while maintaining an appropriate distance from the cart by adjusting the force of its arms to push a cart using the force 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 maximum load is 10 kg.)

ASIMO

Aiming for Even More Progress

ASIMO will truly

be able to help people

in the 21st century.

Honda's dream is that

ASIMO will help improve life

in human society.

Staying true to our

'Challenging Spirit,'

Honda's research & development

will continue with **ASIMO**,

to realize our dreams

for the future.

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