

Italy-Japan 2007 Workshop "Robots are already among us"

Safety Standardization Activities on Service Robots

TOYOTA MOTOR CORPORATION
Partner Robot Development Div.
Yasuhiro Ota, Ph.D.

TOYOTA

TOYOTA PARTNER ROBOT

Contents

1. Basic Concept on Machine Safety
2. Recent ISO Standardization Activities
3. Example with Toyota Care Robot
4. Typical Apprehensions in Practical Use



TOYOTA

TOYOTA PARTNER ROBOT

Contents

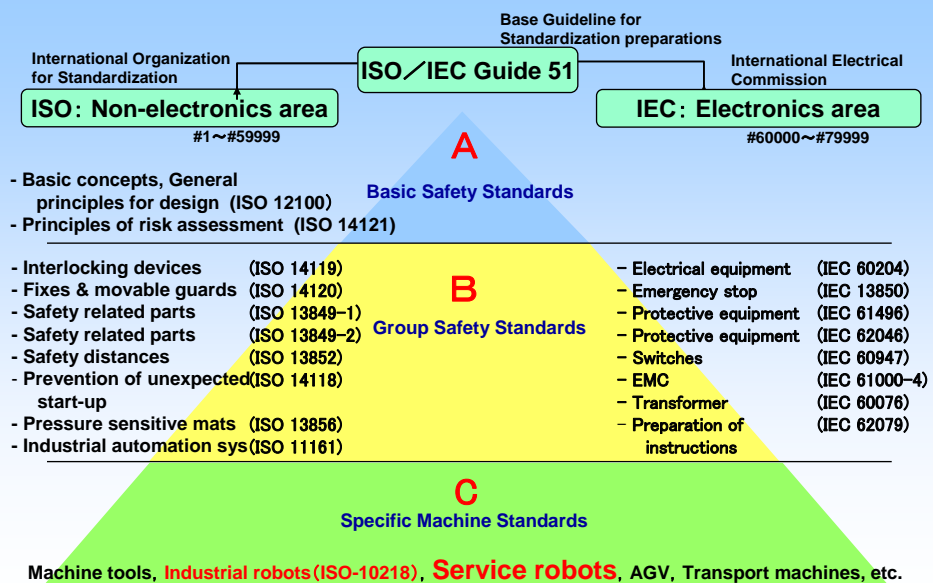
1. Basic Concept on Machine Safety
2. Recent ISO Standardization Activities
3. Example with Toyota Care Robot
4. Typical Apprehensions in Practical Use



TOYOTA

TOYOTA PARTNER ROBOT

ISO/IEC Standardization Structure



TOYOTA

TOYOTA PARTNER ROBOT

Philosophy of Machine Safety under ISO Standards

“How to prevent an accident”,
“How to claim liability on an accident”

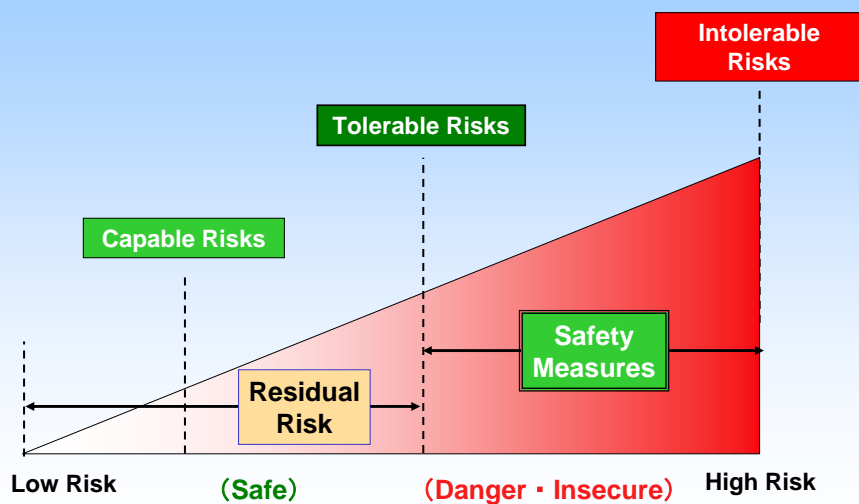
Transition

“How to tolerate an accident”,
“How to prevent accidents beyond tolerable ones”

TOYOTA

TOYOTA PARTNER ROBOT

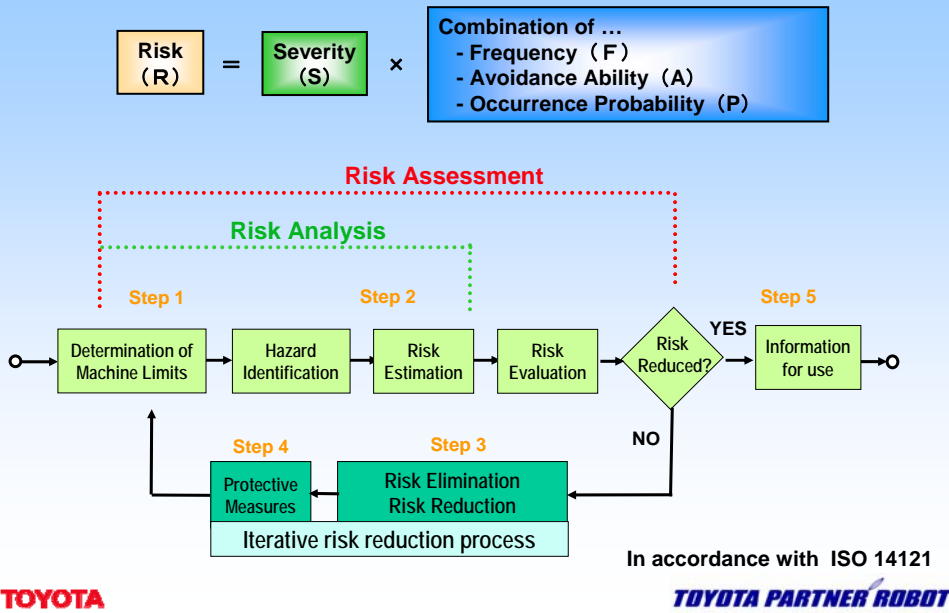
Philosophy of Machine Safety based on Risk



TOYOTA

TOYOTA PARTNER ROBOT

Risk Assessment Process



Safety Categories and Requirements

Category	Requirements	System Behavior due to System Fault
B	Basic safety principles	Can lead to the loss of safety function
1	Well-tried components & well-tried safety principles	Can lead to loss of safety function but "less probability"
2	Safety function shall be checked at suitable intervals	Can lead to loss of safety function "between checks"
3	Double-check function (a single fault is detected)	Accumulation of undetected faults can lead to the loss of safety function
4	Self-diagnosis function (No accumulation of faults)	Safety function is always performed "regardless of accumulation of faults"

Source: ISO 13849-1

TOYOTA

TOYOTA PARTNER ROBOT

Contents

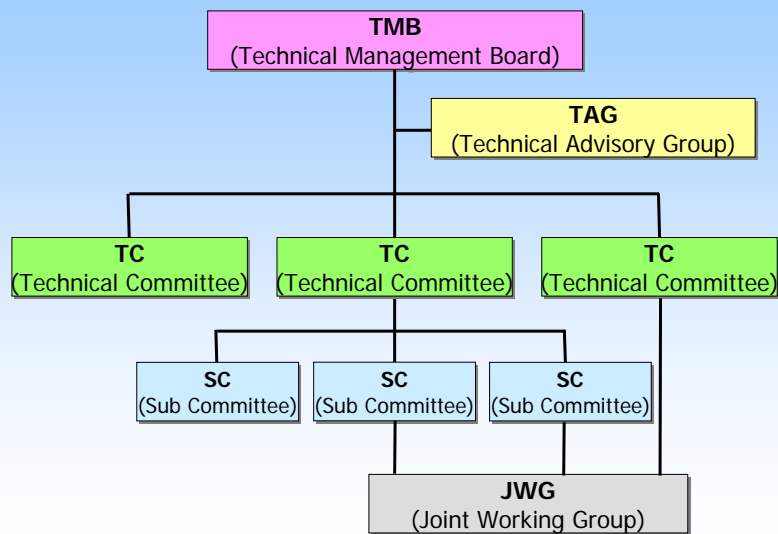
1. Basic Concept on Machine Safety
- 2. Recent ISO Standardization Activities**
3. Example with Toyota Care Robot
4. Typical Apprehensions in Practical Use



TOYOTA

TOYOTA PARTNER ROBOT

ISO Organization Structure



TOYOTA

TOYOTA PARTNER ROBOT

ISO / TC184 / SC2

ISO / TC184 ???

Technical committee that deals with standardization activities on
**“Automation systems and integration
in industrial environment and robotics”**

ISO / TC184 / SC2 ???

Technical committee that deals with standardization activities on
“Robots and robotic devices”



TOYOTA

TOYOTA PARTNER ROBOT

ISO / TC184 / SC2

There are two “Project Teams” (PT1 and PT2) under SC2:

■ PT1 – Robots for Industrial Environments (ISO 10218)

Part 1: “Robot”

→ officially published in June 2006

Part 2: “Robot system and integration”

→ currently under work (2006 ~ 2009)

■ PT2 – Robots in Personal Care (ISO xxxxx)

→ currently under work (2006 ~ 2010)

Part 1: “Non-invasive personal care robots”

Part 2: “Invasive personal care robots”

TOYOTA

TOYOTA PARTNER ROBOT

ISO / TC184 / SC2

ISO / TC184 / SC2 / PT2 “Project Team: *Robots in Personal Care*”

«Participant Countries»

1. Finland
2. France
3. Germany
4. Italy
5. **Japan**
6. Korea
7. Portugal
8. UK



TOYOTA

TOYOTA PARTNER ROBOT

Definition of Service Robots (tentative)

Definition of “Service Robots”:

A robot which provides “usefulness” for the well-being of humans, society and equipment, excluding manufacturing operations.

Toy robots and Military robots are also outside its scope.

Definition of “Robots”:

Reprogrammable machine with a degree of autonomy, programmable in more than one axis, either fixed in place or mobile, and able to perform task(s).

Note: Degree of autonomy can be from manual (including tele-operation) to fully autonomous.

NOTE: The above definitions are still under discussion in ISO/TC184/SC2/PT2, and thus, these are NOT official ones yet.

TOYOTA

TOYOTA PARTNER ROBOT

Normative ISO Reference

Current **ISO 10218-1** standard states that the robot must provide a visual indication when it is in **“collaborative operation”** and comply with one or more of the following:

1. The robot must STOP when a human is in the collaborative workspace
2. In hand-guiding mode, the robot shall operate at a reduced speed (**<250mm/sec**); otherwise, risk assessment is required
3. An appropriate separation distance (ISO 13855) from the operator shall be maintained
4. The robot shall be designed to have a **maximum power of 80W or static force of 150N**

TOYOTA

TOYOTA PARTNER ROBOT

Categorization by Degree of Contact

Type	Degree of contact	Example
1. Minimal invasive surgery robots	Invasive	Da Vinci, RoboDoc
2. Rehabilitation robots	Continuous contact	TEM LX2
3. People carrier robots	Continuous against gravity (active + passive devices –ask Rainer)	i-Foot, Manus, i-Unit, Regina J11
4. Physical assistance robots	Intermittent	Myspoon
5. Treatment and examining robots	Intermittent, radiation contact	CyberKnife
6. Mobile manipulator	Intermittent	Wheelchair+Manus, RoboHiter T1
ETC		

TOYOTA

TOYOTA PARTNER ROBOT

Contents

1. Basic Concept on Machine Safety
2. Recent ISO Standardization Activities
- 3. Example with Toyota Care Robot**
4. Typical Apprehensions in Practical Use

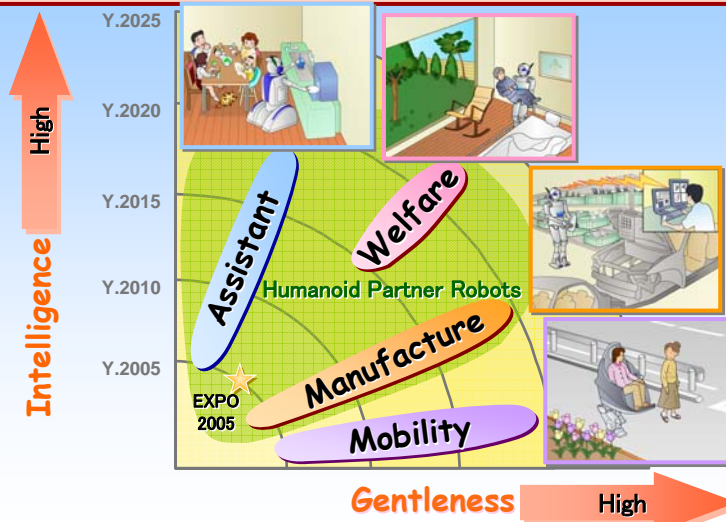


TOYOTA

TOYOTA PARTNER ROBOT

Addressing Societal Issues with Robotics

Support Human Life with Intelligent and Autonomous Partner Robots



TOYOTA

TOYOTA PARTNER ROBOT

Toyota Care Robot

Nursing Applications

- Reduces Burden of Nursing Staff and Family Members
- Allows Nursing Staff to Focus on Patient Care

Grab my drink, please!

Key Features

①Voice Communication
"Be right there!"

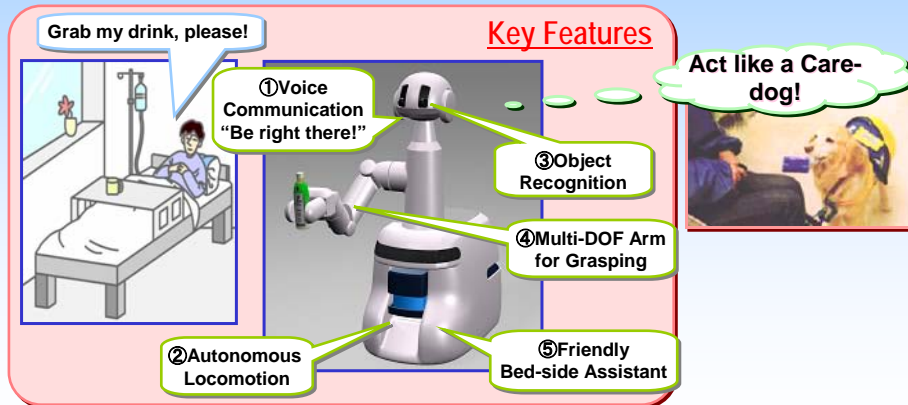
②Autonomous Locomotion

③Object Recognition

④Multi-DOF Arm for Grasping

⑤Friendly Bed-side Assistant

Act like a Care-dog!



TOYOTA

TOYOTA PARTNER ROBOT

Toyota Care Robot (1st Prototype)

Japanese Circulation Society Conference (Nagoya, March 2006)

Toyota Care Robot
Video Presentation

Delivery20060315BlockC

TOYOTA

TOYOTA PARTNER ROBOT

Potential Hazards on Toyota Care Robot

Typical Potential Hazards

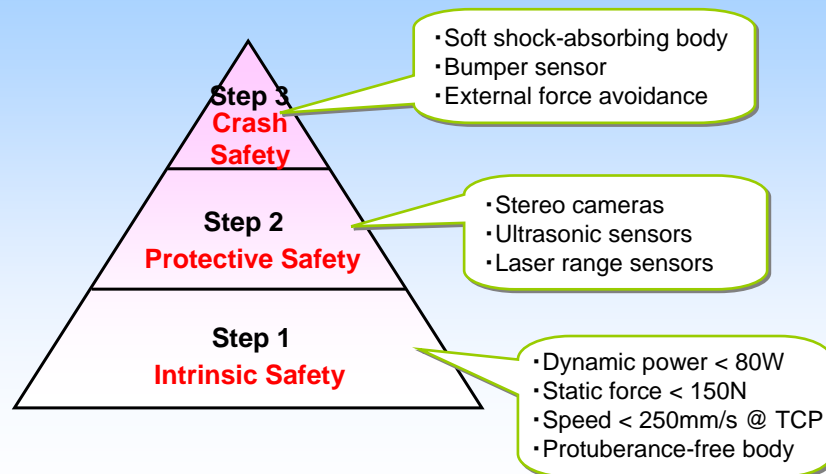
Principal Hazard	Energy Type	Potential Area of Hazard
Pinch	Static force by motor(s)	Head
		Shoulder (armpit)
		Elbow (inside)
		Between arm and torso
		Between torso and ambient wall
Unstable Fall	Potential energy	Robot itself
Impact	Kinetic energy	Manipulator(s)
		Robot itself
Electrification	Electric energy	Contact with electrical wire terminal(s)
Burn	Heat energy	Contact with electrical wire terminal(s)
Intoxication	Poison	Exposure to robot paints
E-mag Waves		Electromagnetic radiations to pacemaker(s)
		malfunction of medical equipment(s)
		malfunction of robot from extraneous e-mag radiations

TOYOTA

TOYOTA PARTNER ROBOT

3-Step Method

3-Step Method on Safety Measures



TOYOTA

TOYOTA PARTNER ROBOT

FMEA on Toyota Care Robot

FMEA = Failure Mode and Effect Analysis

Frequency	Rank	Status										
	5	Frequent	C	B3	A1	A2	A3	Unhurt	Mild	Medium	Serious	Fatal
4	Often	C	B2	B3	A1	A2	1	2	3	4	5	Rank
3	Occasionally	C	B1	B2	B3	A1						
2	Rare	C	C	B1	B2	B3						
1	Impossible	C	C	C	B1	B2						

Severity

Definition of Ranks

Severity	Rank	Situation	Definition
	5	Fatal	Dead
4	Sereious	Existence of aftereffects	
3	Medium	No aftereffects but frequent hospital visit (less than a month)	
2	Mild	No periodical hospital visit but light injury (less than a week)	
1	Unhurt	No injury	

Frequency	Rank	Status	Definition
	5	Frequent	No statistical data exist → Need further survey
4	Often	No statistical data exist → Need further survey	
3	Occasionally	No statistical data exist → Need further survey	
2	Rare	No statistical data exist → Need further survey	
1	Impossible	No accident	

TOYOTA

TOYOTA PARTNER ROBOT

Contents

1. Basic Concept on Machine Safety
2. Recent ISO Standardization Activities
3. Example with Toyota Care Robot
4. Typical Apprehensions in Practical Use



TOYOTA

TOYOTA PARTNER ROBOT

Apprehensions in Practical Use

◆ Scope of Service Robots ???

- Power suits ?
- Passenger carrier robots (Segway, intelligent wheelchairs, etc.) ?

◆ Ethics of Service Robots ???

- How much close to human is acceptable ?

◆ Product Recall of Service Robots ???

- Need (national or ISO) standards also ?
- Level of appropriate recall conditions ?

◆ Insurance / Indemnity ???

- Need professional opinions from:
layers, insurance office, medical doctors, etc.

TOYOTA

TOYOTA PARTNER ROBOT

Apprehensions in Practical Use

◆ Risk Estimation ???

No statistical data on “Frequency” yet

→ Various cases...

- Infants to senior citizens,
- Healthy persons to handicapped persons, etc.

◆ Safe Design Parameters ???

Other than Force, Power, and Speed (required in ISO 10218-1)

→ Additional parameters, such as...

Momentum, Energy, Stiffness, Clearance, Torque, etc.



TOYOTA

TOYOTA PARTNER ROBOT