Panasonic

An Evaluation Technology of Safe Contact with Humans for Collaborative Robot by Pain Sensing System

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Workshop－HRC: Biomechanical Limits, Modeling and Testing to Support Safe Robot Contacts with Humans

パナソニック株式会社 プロダクト解析センター
Panasonic Corporation Product Analysis Center

Today's Outline

1. Introduction of Panasonic
2. Background of Research
3. Development of Pain-Sensing Dummy

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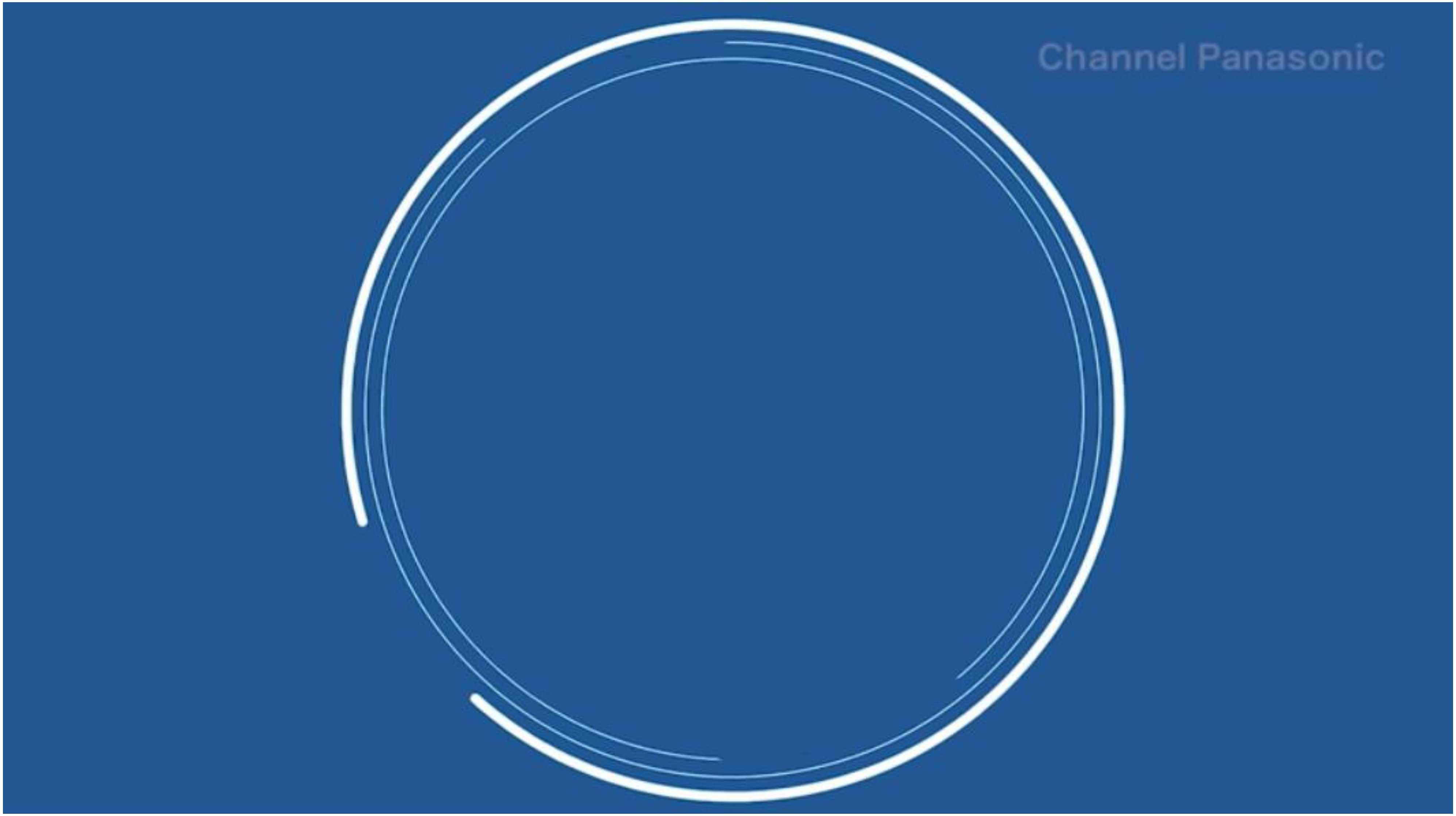
Introduction of Panasonic



3 Technologies in Panasonic

Production tech

Manufacturing tech

Quality evaluation Analysis tech

<Productive department>
Function・Efficiency,
Miniaturization,
Energy saving, etc.

<Manufacturing department>
Automation,
High efficiency, etc.

<Product analysis center>
Quality satisfaction according to the customer requirement,
Value creation, Quality evaluation,
Trouble solving, etc.

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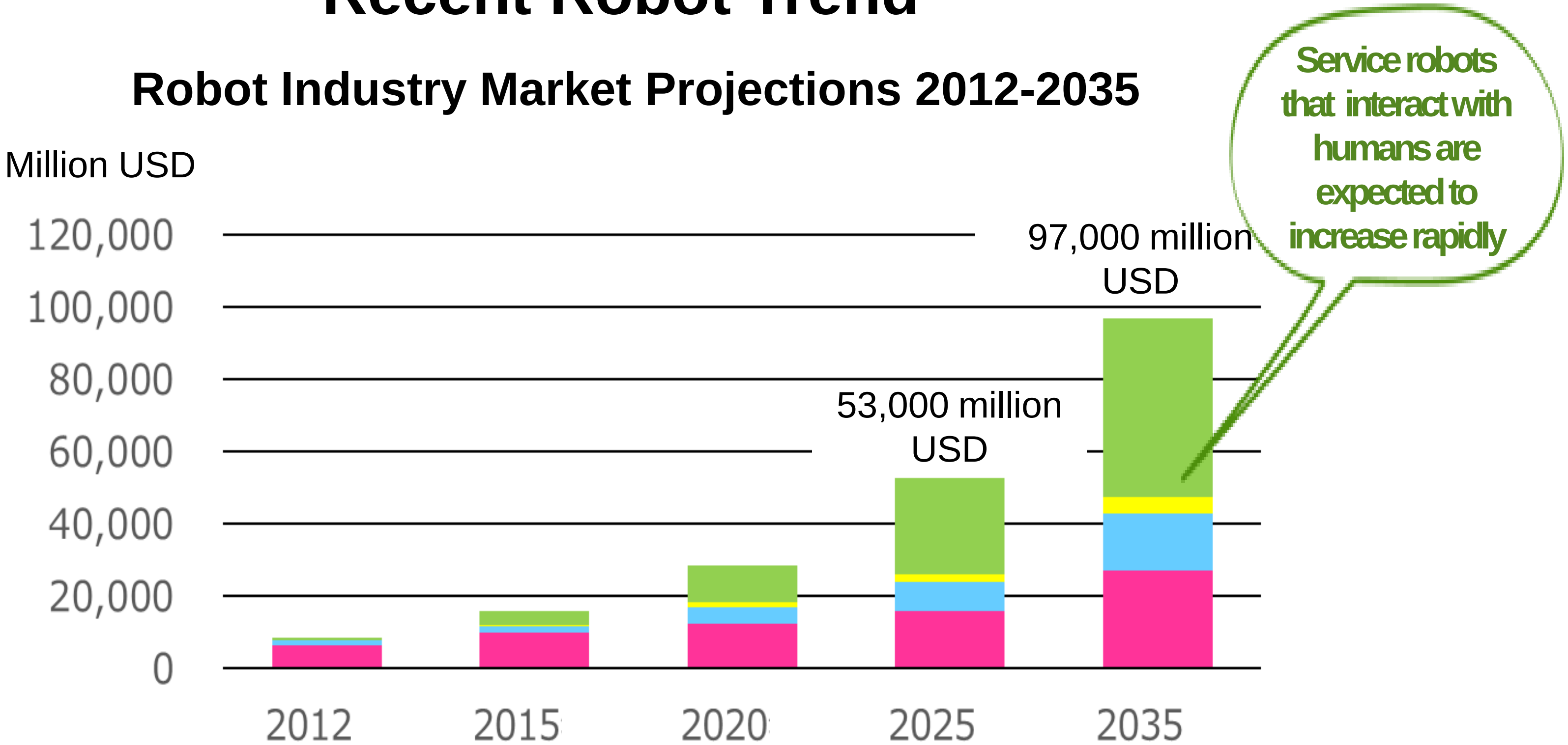
Recent Robot Trend

Robot Industry Market Projections 2012-2035



	2012	2015	2020	2025	2035
Total	8,600	15,990	28,533	52,580	97,080
Service area	600	3,733	10,241	26,462	49,568
Agriculture	10	467	1,212	2,255	4,663
Robotech Product	1,400	1,771	4,516	8,057	15,555
Manufacturing	6,600	10,018	12,564	15,807	27,294

Source: NEDO (2010), METI (2012)

（Unit：million USD＊）

・Not only industrial robot anymore, but also logistics, collaborative, healthcare, rehab, elder care, indoor, …

＊exchange rate 100JPY = 1USD

Our Robots and Concept

Issue of Service Robot

Advertising robot demonstration experiment in Narita Airport Feb 2018

Robots that can move autonomously safely even in crowded place are required

Robot Safety Focus Area

Unavoidable contact with humans

Pain

A : Intolerable risk area
B : As low as reasonably practicable area
C : Safety area

Occurrence Frequency (High ↑ / Low ↓)	not hurt	mild	critical	serious	fatal
frequently	C	B	A	A	A
occasionally	C	B	B	A	A
sporadically	C	B	B	B	A
rarely	C	C	B	B	B
very little	C	C	C	B	B
hardly	C	C	C	C	C

Degree of hazard: Low ← → High

R-Map in risk assessment

- Design the degree of hazard to be <u>as low as possible</u> where there is high possibility of contact
- Pain threshold was used to distinguish between 「not hurt」 and 「mild」
- New pain evaluation method establishment is necessary

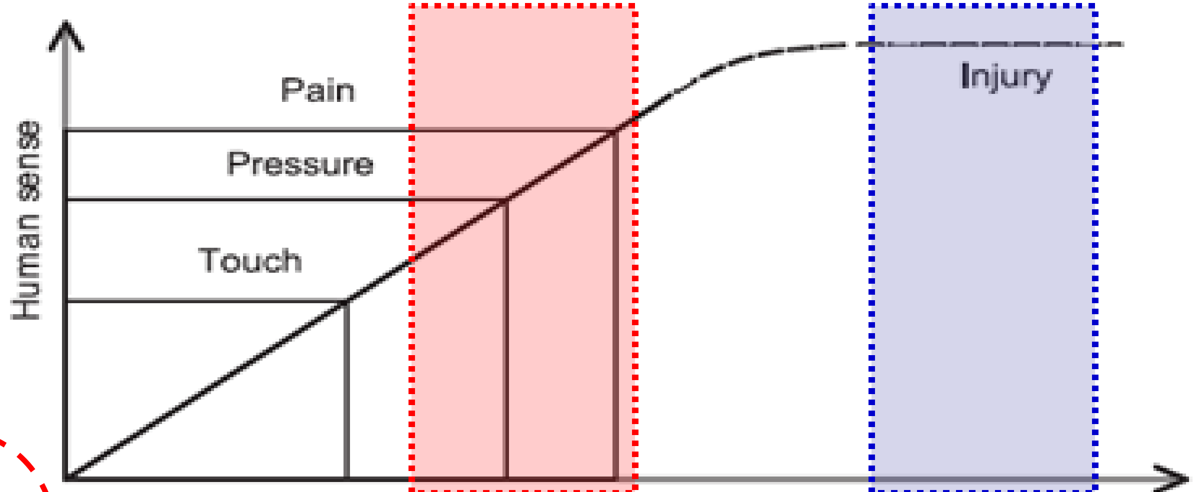
Development of Pain-sensing Dummy

【Objective】 To develop a new dummy that can evaluate "Pain" limits without injury during contact between human and robot

Risk area required for service robots

Start to feel Pain・Discomfort
Low level of harm

Bone fracture
High level of harm



Evaluated by this development

Evaluated by conventional dummy

Crash test dummy Hybrid-III

Head dummy

Finger dummy (for laceration)

Finger dummy (for bone fracture)

Source: Y. Ikeda and T. Saito, JNIOSH

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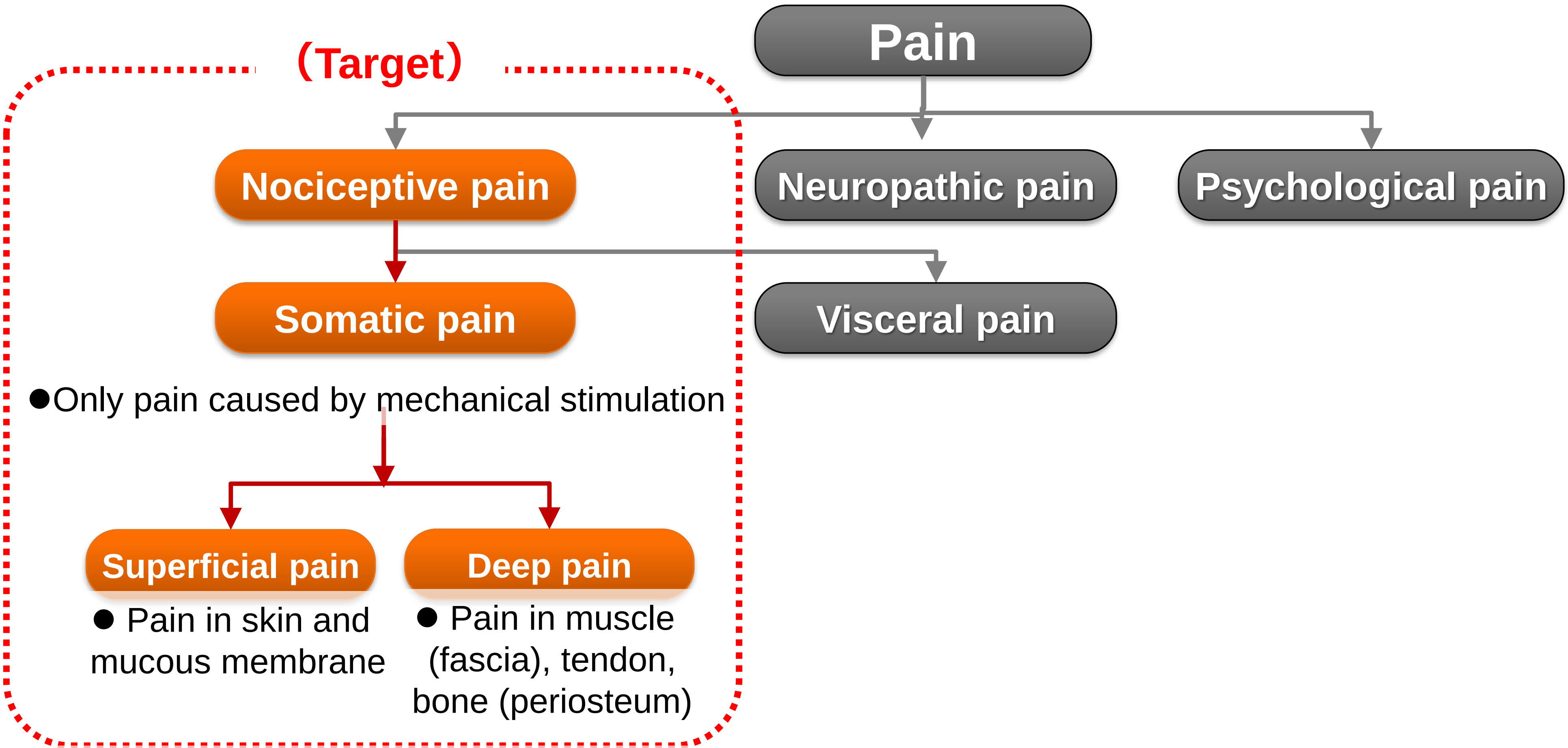
Concept of Pain-sensing Dummy

Evaluation area targeted by Pain-sensing dummy

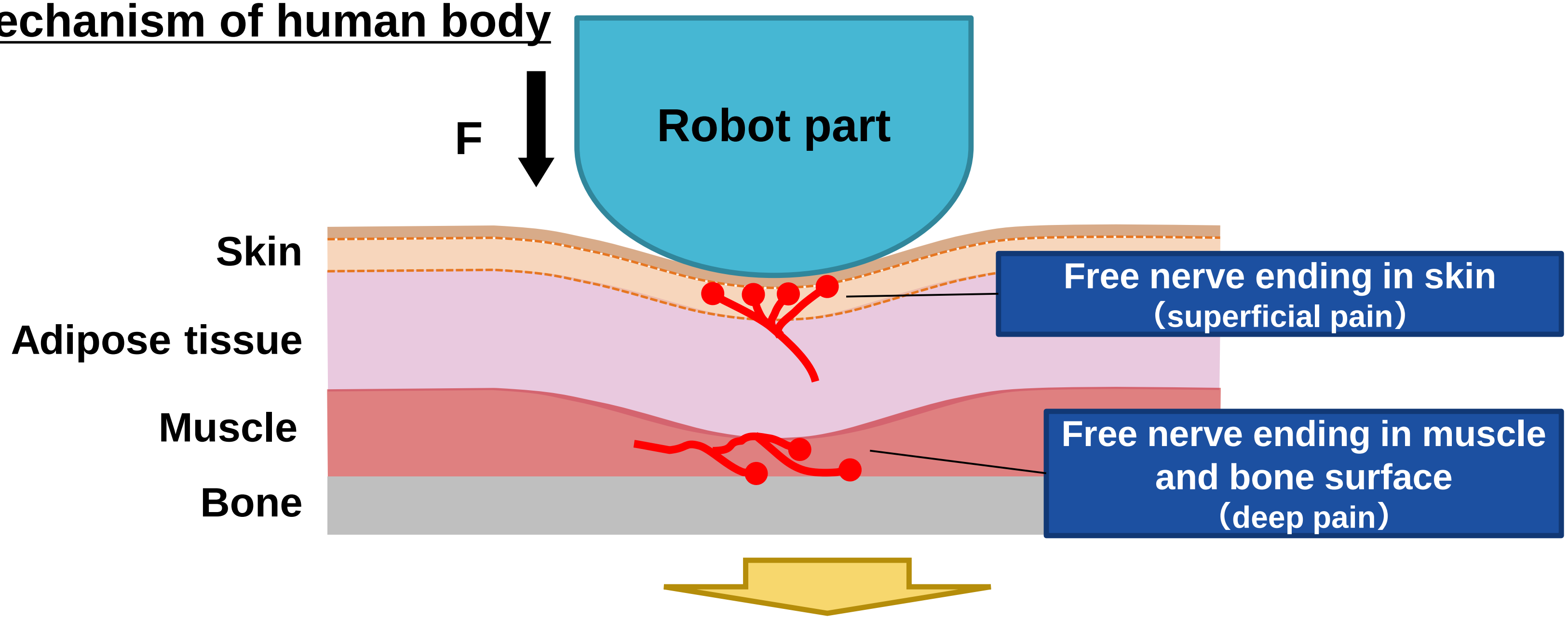
Pain classification and target



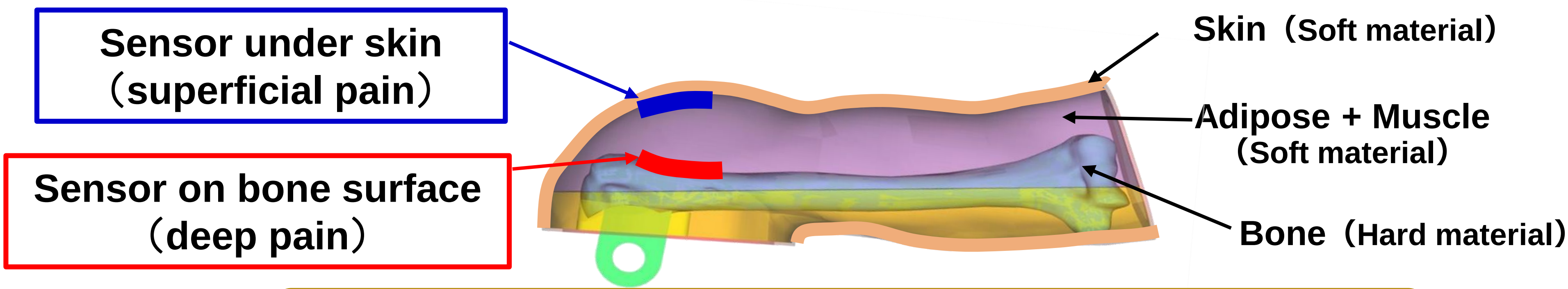
※However, pain for sharp objects that cause cutting wound is excluded

Concept of Pain-sensing Dummy

Pain mechanism of human body



Pain-sensing dummy structure (Upper arm)



Imitate pressure distribution related with human pain

Volunteer Experiment to Verify Dummy

Comparing human pain with dummy evaluation results, the pressure at pain-onset threshold was clarified

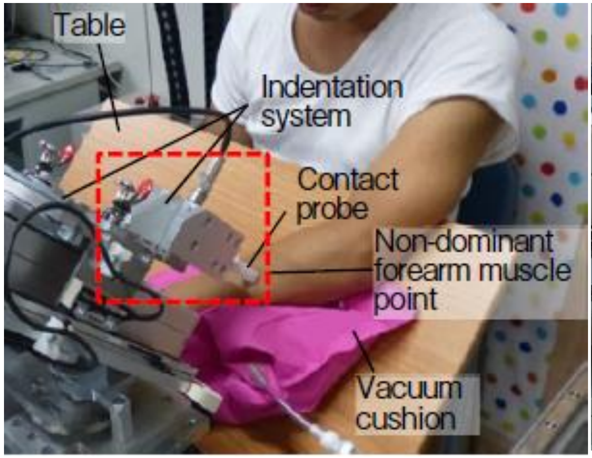
【Point】

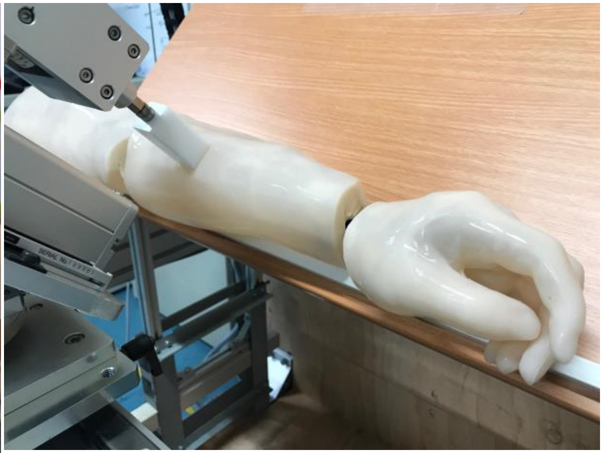
- **Indentation equipment for pain measurement was developed**
- **Ethics committee（PB2018-1) approved**
- **To verify biofidelity, dummy and volunteer experiments were conducted**

Specification

- Max load 500N
- Displacement 120mm
- Adjustable joint
- quasi-static load test

Indentation equipment



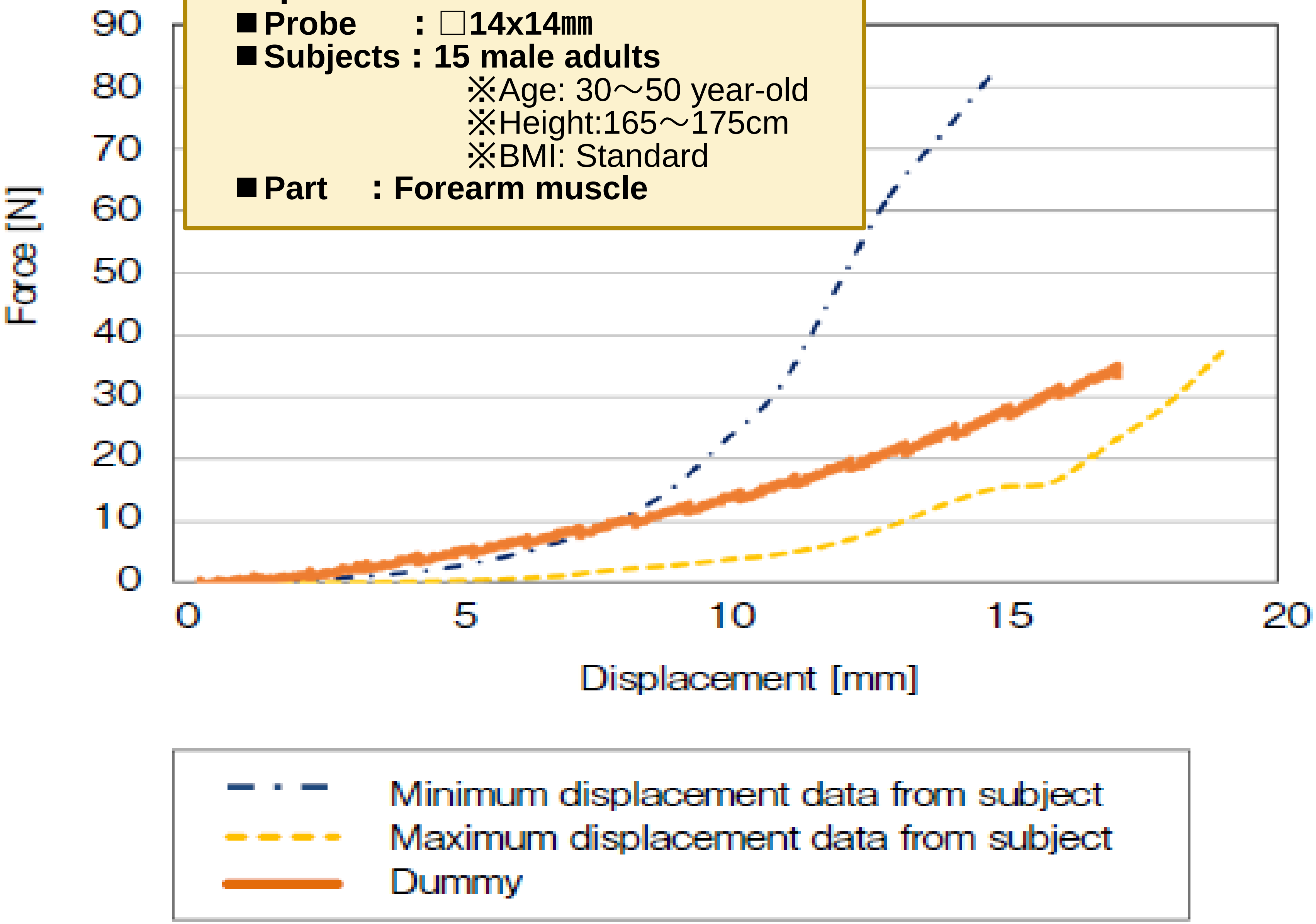


Volunteer and dummy experiments

Biofidelity Verification

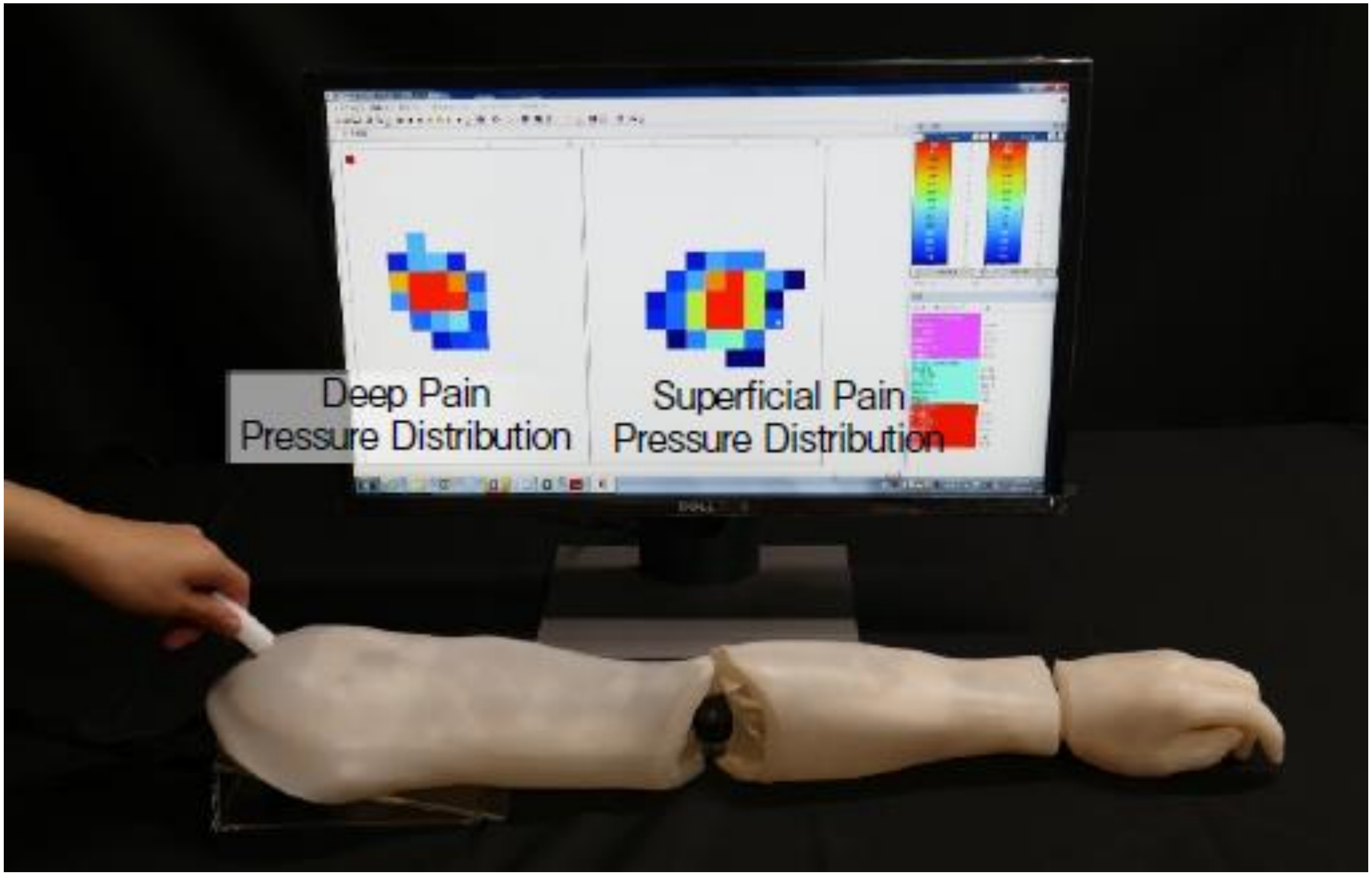
<Experimental Condition>

- **Probe : □14x14㎜**
- **Subjects : 15 male adults**
  - ※Age: 30～50 year-old
  - ※Height:165～175cm
  - ※BMI: Standard
- **Part : Forearm muscle**



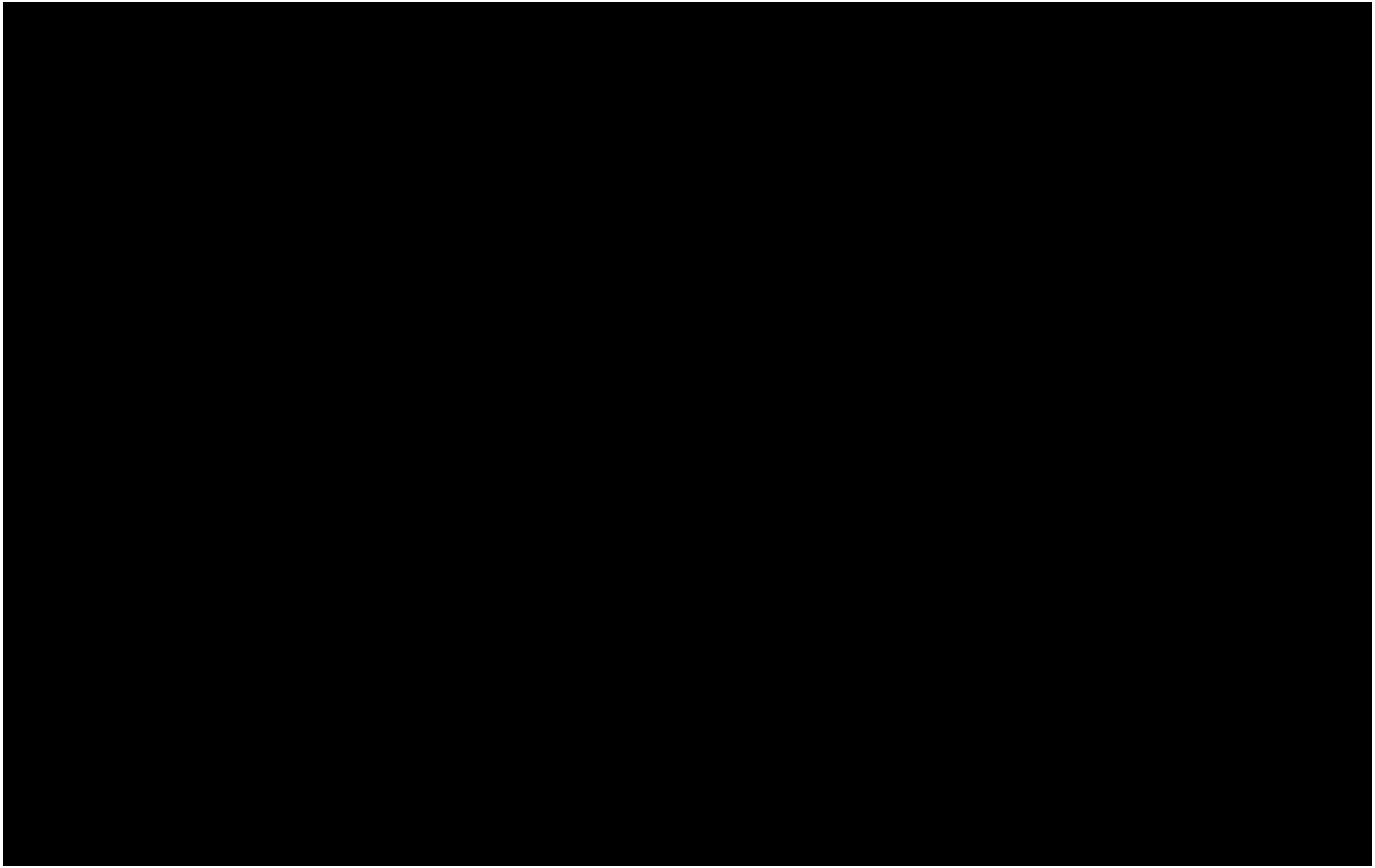
Pain-sensing Dummy System

• **Designed by consulting with pain specialist (M.D.)**



Pain-sensing Dummy（arm part）

The Contact Area Affect between Superficial and Deep Pressure



A Part of Experiment Results

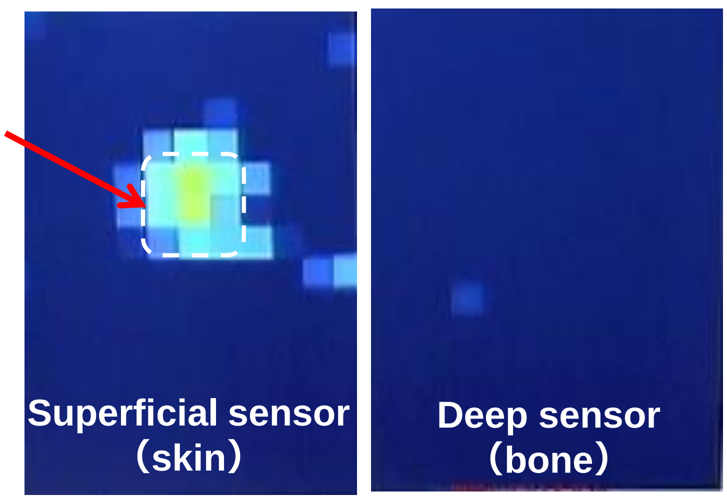
Pressure distribution inside dummy when the probe is in contacted

Pressed at forearm muscle by small probe□7x7mm

Pressed at forearm muscle by bigger probe□24x24mm

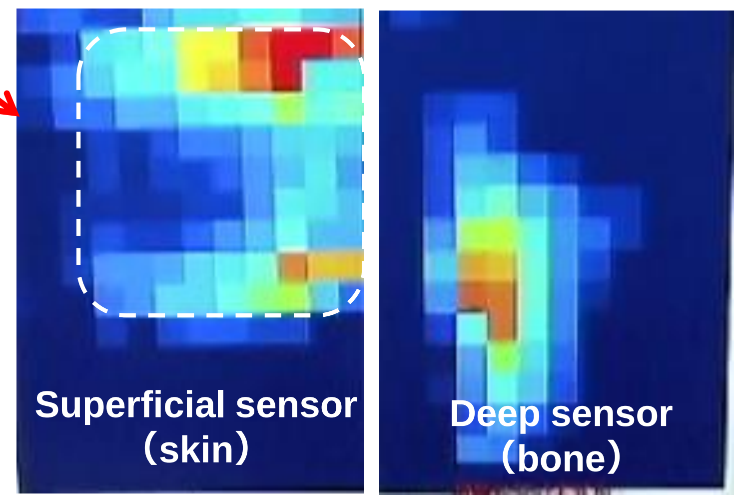
Superficial sensor detected strong pressure

White dot line is probe size



Deep sensor also detected strong pressure

White dot line is probe size

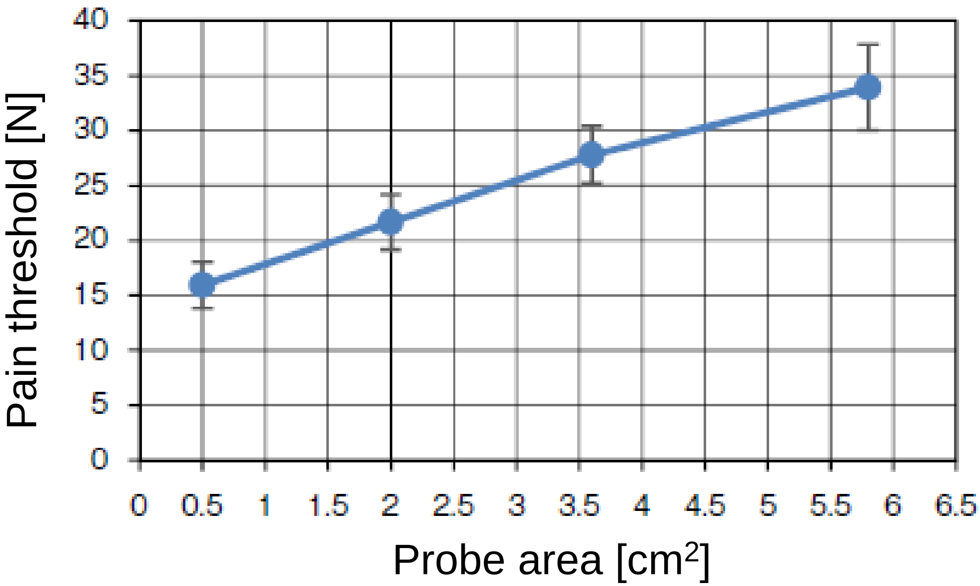


Pain-onset Volunteer Experiment Result

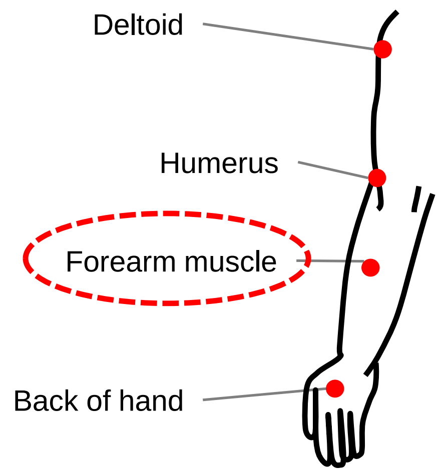
Comparing human pain with dummy pressure results

・**Pain-onset** volunteer experiment was conducted

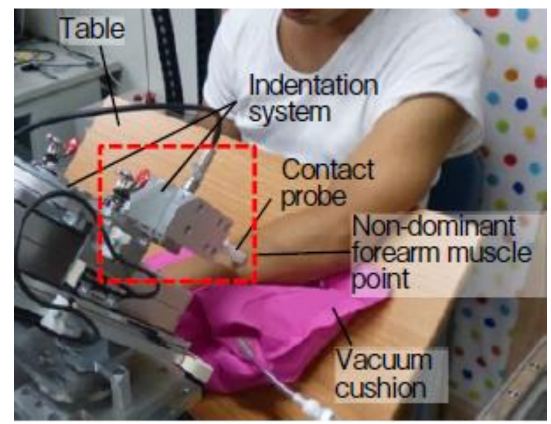
・The same amount of **pain threshold (N)** were repeated with dummy to evaluate **pressure**



Average pain-onset results from 15 male adults on forearm muscle point



Measurement point



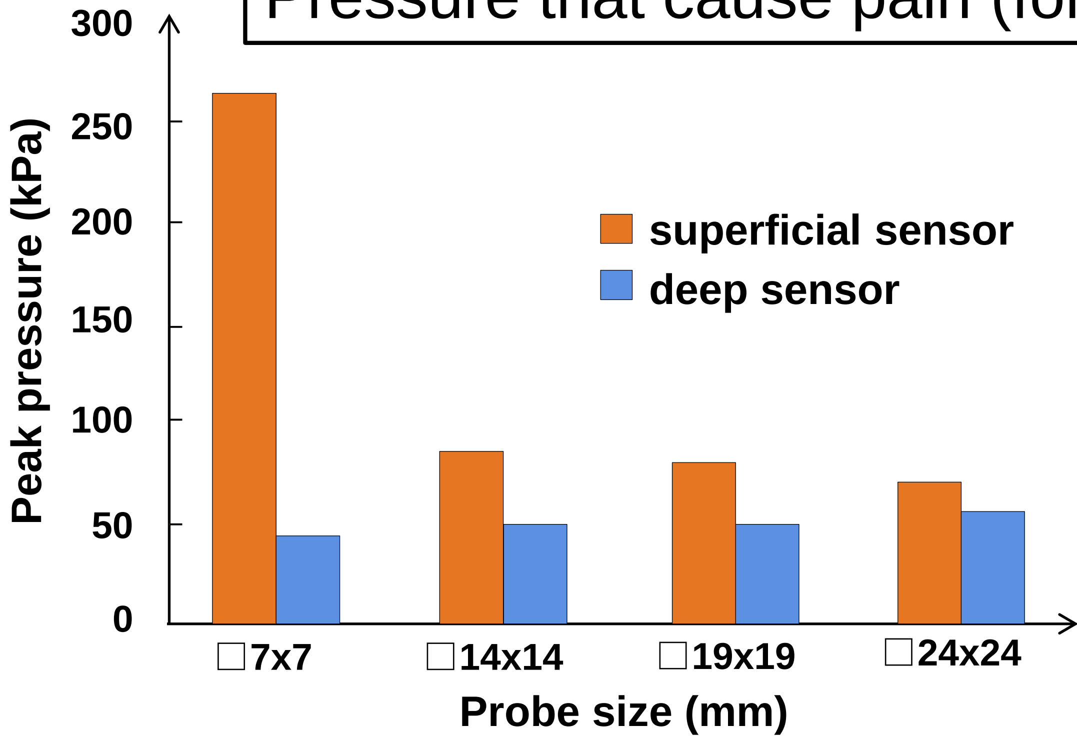
During experiment

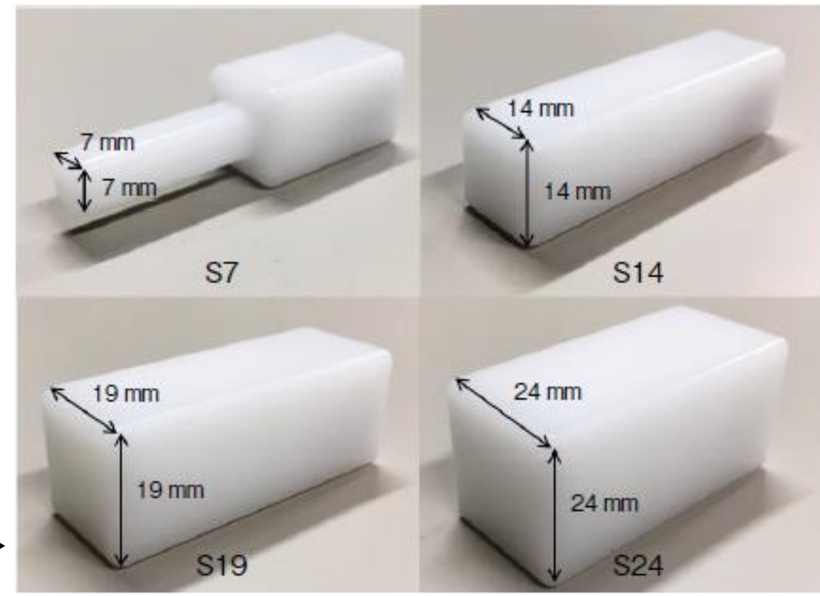
Volunteer tests

Development of Pain-sensing Dummy Result

Comparing human pain with dummy evaluation results

Pressure that cause pain (forearm muscles)

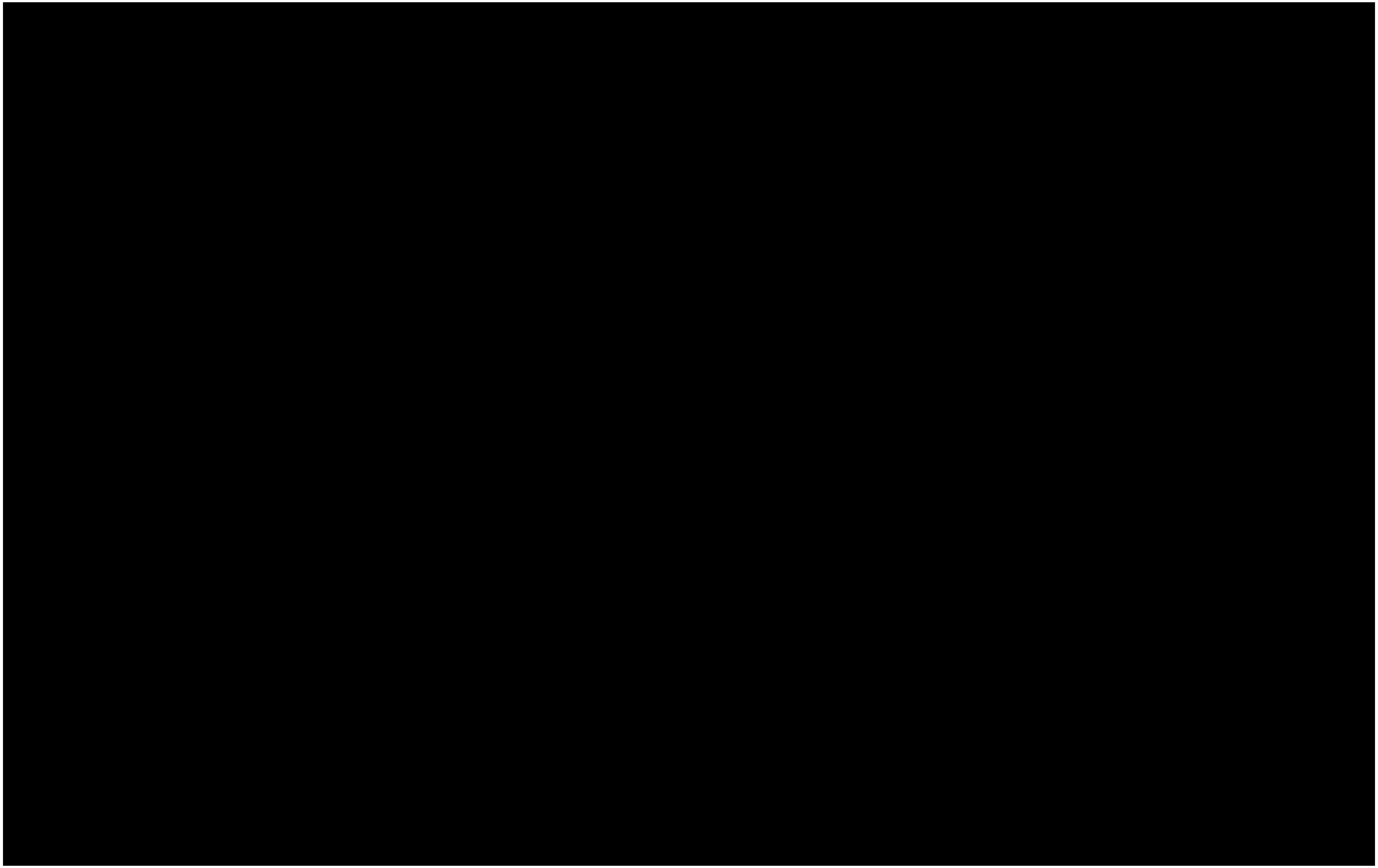




- **In probe□7x7, the peak pressure of superficial sensor is high**
- **In deep sensor, no significant difference were observed for any probe**
- **Contact area are important factor for pain evaluation**

Ref: P. Tanyaporn et al., "Contact are effects on superficial and deep pain threshold for service robot safety design using a pain-sensing system" PTJ. Vol.65, no.1, pp.21-26, 2019

Collision Experiment of Service Robot



Development Summary

1. Pain-sensing dummy was developed

Biofidelity of dummy placed by two pressure sensors (**superficial** and **deep** sensors) was verified that have **similar mechanical property to humans**

2. Dummy experiment was conducted

We were able to confirm that we can measure the difference between two types of pain

3. Quasi-static volunteer experiment

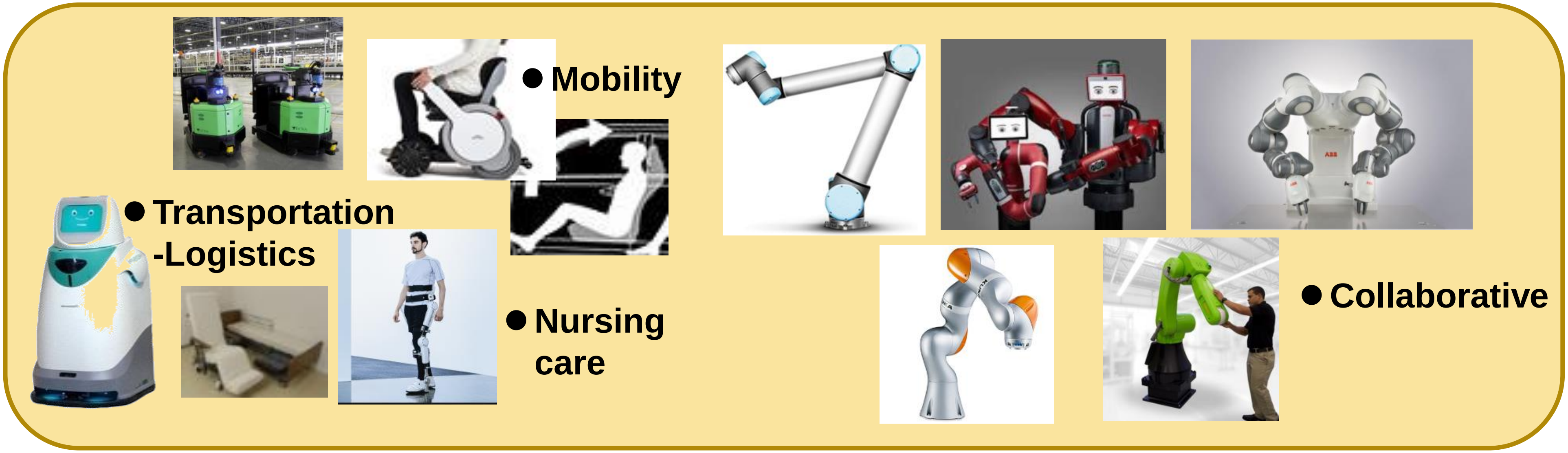
The relationship between **pain force** and **internal pressure** was clarified

⇒Be able to analyze pain level during collision between human and robot

Future's Challenge

1. More research on superficial and deep pain relationship
2. Evaluation in all parts of body and attributes (males, females, elders, children)
3. Dynamic condition

Contribution to Safety Design for Human-robot Collaboration



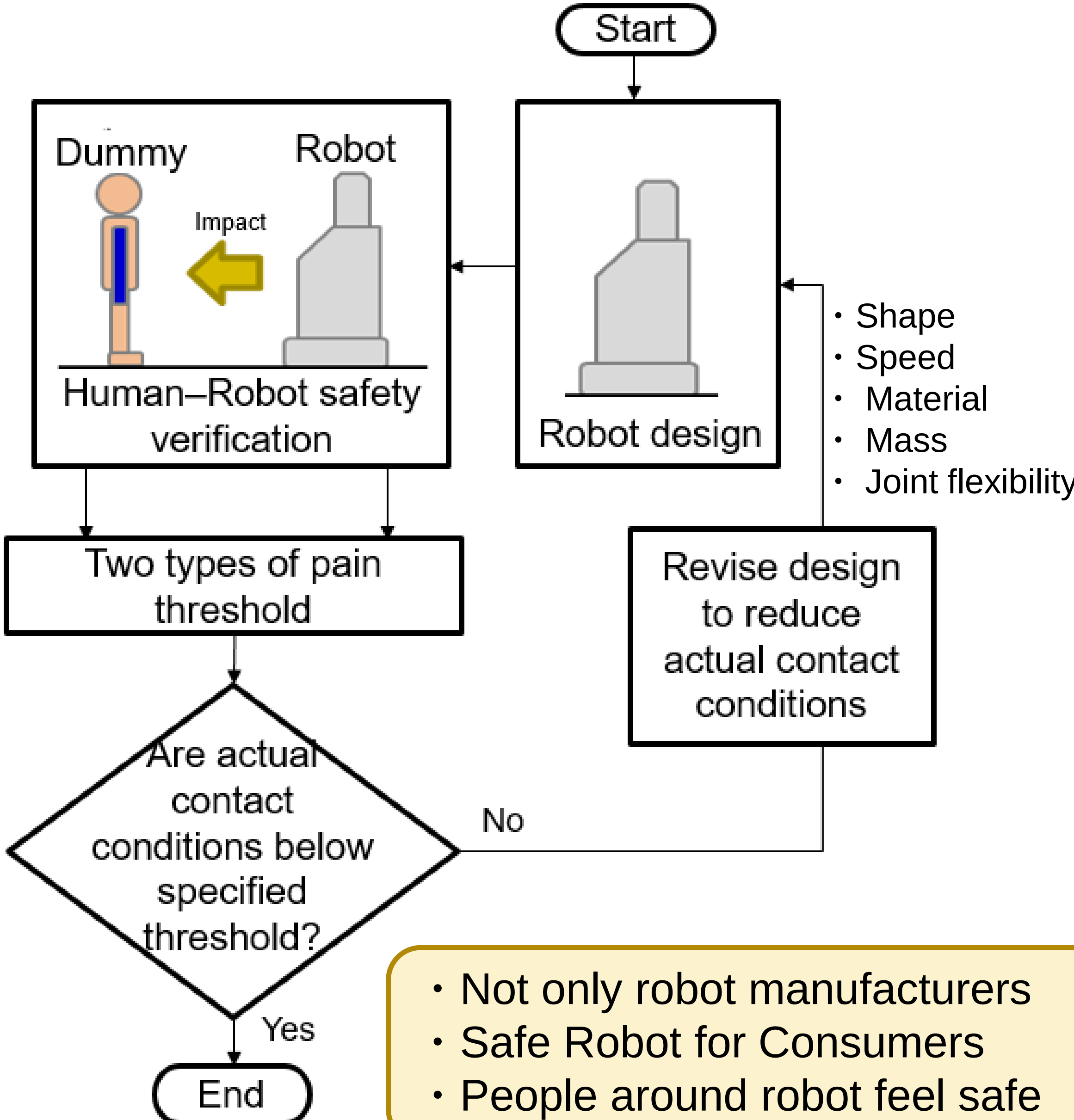
＜Safety design strategy＞

Pain-sensing dummy evaluation result

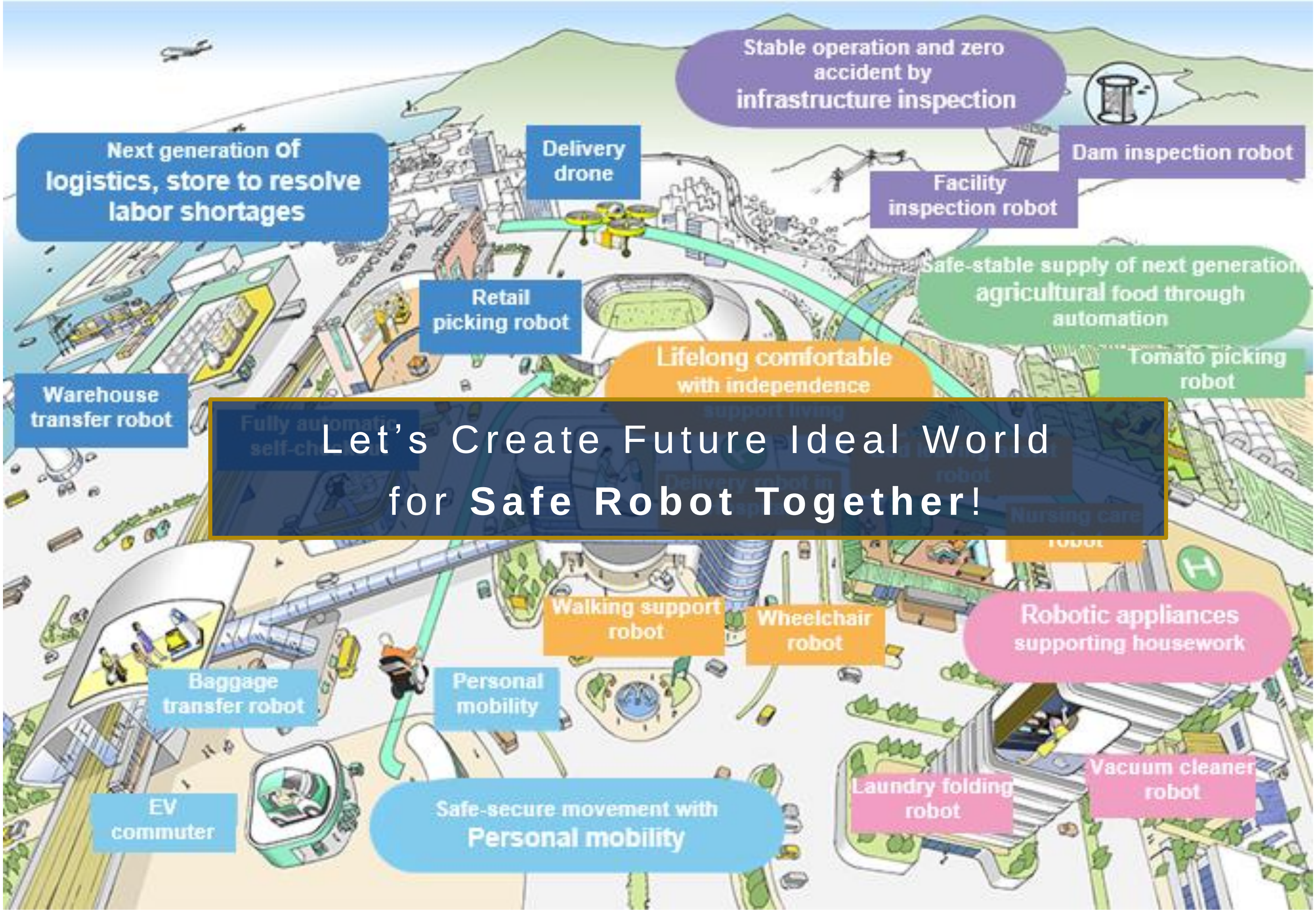
		Software (Control)	Hardware	
Before Collision	Collision Avoidance	Distance		
	Impact Minimization	Speed Posture	Load	
After Collision	Impact Absorption-Distribution	Posture	Surface material Joint flexibility	Surface shape

Ref: I. Koji et al., “Safety evaluation method of design and control for human-care robots” IJR. Vol.22, no., pp.281-297, 2003

Example of Collaborative Robot Design



- Not only robot manufacturers
- Safe Robot for Consumers
- People around robot feel safe


Stable operation and zero accident by infrastructure inspection
Dam inspection robot
Facility inspection robot
Next generation of logistics, store to resolve labor shortages
Delivery drone
Retail picking robot
Warehouse transfer robot
Safe-stable supply of next generation agricultural food through automation
Tomato picking robot
Lifelong comfortable with independence
Let's Create Future Ideal World
for Safe Robot Together!
Walking support robot
Wheelchair robot
Robotic appliances supporting housework
Baggage transfer robot
Personal mobility
EV commuter
Safe-secure movement with Personal mobility
Laundry folding robot
Vacuum cleaner robot

Feature/Core competence of Product Analysis Center

Thank you for your attention