<u>Investigation of the Use of Humanoids for Industrial Robot Safety Standards</u>

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Abstract

It is quite possible that in the future, the Next Generation Robots (NGRs) will work with humans in industrial sectors to lift heavy materials, fetch parts, assist in mounting parts, etc. Gradually the physical safety barriers surrounding these industrial robots will be replaced with virtual barriers such as sensors and safety controllers. The mixing of humans, humanoids, and industrial robots will depend on the safety of the affected workers. This study looks for the availability of humanoid robots, which could be used, to test industrial robots safety systems. Because the study was conducted using public information, not every field for all the humanoids can be completed.

Introduction

Current means of addressing the human-robot interaction safety problem involve restricting human access to significant portions of valuable manufacturing production floor space and investing significant resources in protective equipment. NGR, with built-in safety technology, is an enabling technology, which can affect the development of markets in those many classes of products requiring repeatable autonomous operation, handling of hazardous or heavy loads, etc. For example, this technology can reduce the cost of automobile manufacturing, microelectronic manufacturing, surgical operations, rehabilitation and elderly care, etc. There are at least 100,000 industrial robots in use in the U.S. and approximately 700,000 throughout the world. Approximately 10% of them are replaced annually. Their cost ranges from approximately $30,000 to $50,000 per unit. However, the cost of protective equipment is approaching the cost of the robotic units themselves. Overall, the current size of this market is approximately $4.2 to $7.0 billion. A serious impediment of technological progress in this area is the potential for robots to cause serious injury when they come in close proximity to humans. Safety features must be built into the NGR and those features validated for effectiveness of protection.

Objectives

Explore various designs of instrumented humanoid robots that can be used as standard test guinea pigs for the evaluation of the safety of the Next Generation of Robots (NGR), which will be designed with safety features that allow them to freely interact with humans. Data from the humanoid robots will enable safety claims to be validated and perhaps result in ratings similar to those obtained from crash dummies by the Insurance Institute for Highway Safety. The experience from these tests will be used to develop standard humanoid robot motion and action tests for the evaluation of the safety of industrial robots and will be submitted to the appropriate standards writing committee and the Occupational Safety and Health Administration (OSHA) for approval.

Accumulated Data

Several tables were generated (listed below), using published data, which compare key features of various humanoids that can be very useful for the selection of the appropriate humanoid for specific safety tests.

Size Comparison[1]

Name	Height (cm)	Width (cm)	Depth (cm)	Mass (kg)
Toyota trumpeter [3]	120			35
JVC J4 [4][5]	20			0.77
Honda ASIMO [6][7][8]	130	45	37	54
Fujitsu HOAP-2 [9][19]	50	24.5	15.7	7
Sarcos DB [10]	185			80
Sony SDR-4X [11][12][13]	58	26	19	6.5
JSK Laboratory at the University of Tokyo's H6 [14]	137	59		55
Kawada Industries, Inc.'s HRP-2 [15][16][17]	154			58
CMST's BHR-1 [18]	158			76

Degrees of Freedom (DOF) Comparison

Name	DOF Arms	DOF Hands	DOF Torso	DOF Legs	DOF Total
Human (actual homo sapiens)	14			12	
JVC J4 [4][5]					26
Honda ASIMO [6][7][8]	14	4	1	12	34
Fujitsu HOAP-2 [9][19]	8	2	1	12	25
Sarcos DB [10]					30
Sony SDR-4X [11][12][13]	10	10	2	12	38
JSK Laboratory at the University of Tokyo's H6 [14]	14			12	35

[1] Certain commercial products and processes are identified in this paper to foster understanding. Such identification does not imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the products and processes identified are necessarily the best available for the purpose.

Kawada Industries, Inc.'s HRP-2 [15][16][17]					30
CMST's BHR-1 [18]					32

Moving Speed Comparison

Name	**Walking speed (km/h)**	**Running Speed (km/h)**
Human (actual homo sapiens) [1][2]	5.23	27
Honda ASIMO [6][7][8]	2.7	6
Sony SDR-4X [11][12][13]	1.2*	
Kawada Industries, Inc.'s HRP-2 [15][16][17]	2	
CMST's BHR-1 [18]	1	

*1.2 smooth surface, .36 rough surface

Power Requirements Comparison

Name	**Power**
JVC J4 [4][5]	Lithium Ion Battery
Honda ASIMO [6][7][8]	Rechargeable 51.8V Lithium Ion Battery
Fujitsu HOAP-2 [9][19]	(1)External power supply: DC24VDC-6.5A (2)Internal battery: Form: NiMH; Voltage: 24VDC; Capacity: 2150mAh
Sony SDR-4X [11][12][13]	Internal battery
Kawada Industries, Inc.'s HRP-2 [15][16][17]	NiMH Battery DC 48V 14.8Ah

Operating Time, Cost, Availability Comparison

Name	**Operating Time (h)**	**Cost ($)**	**Availability Info**
JVC J4 [4][5]	1.5		Prototype only
Honda ASIMO [6][7][8]	1	1,000,000	46 Asimos in existence, can be hired out for $166,000 per year
Fujitsu HOAP-2 [9][19]		50,000	Commercially available
Sarcos DB [10]		1,000,000	
Sony SDR-4X [11][12][13]	1	60,000	
Kawada Industries, Inc.'s HRP-2 [15][16][17]			General Robotix is commercializing the HRP

Grasping Force Comparison

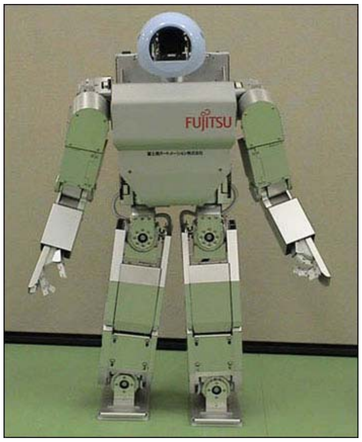
Name	Grasping Force (kN/hand)
Honda ASIMO [6][7][8]	5
Kawada Industries, Inc.'s HRP-2 [15][16][17]	20

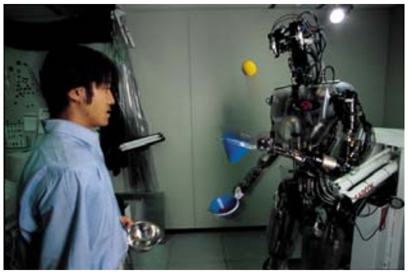
Pictures of Humanoids

Toyota trumpeter [3]

Honda ASIMO [6][7][8]

JVC J4 [4][5] 

Fujitsu HOAP-2 [19] 

Sarcos DB [10] 

Sony SDR-4X [11][12][13] 

JSK Laboratory at the University of Tokyo's H6 [14]

Kawada Industries, Inc.'s HRP-2 [15][16]17]

CMST's BHR-1 [18]

Conclusions

The field of industrial humanoids is very active and is still evolving. A lot of very ingenious devices exist, which could form the basis for future NGR safety testers. These devices have the potential to perform thorough NGR safety tests without endangering human lives.

References

Human
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[15] http://www.kawada.co.jp/global/ams/hrp_2.html
[16] http://findarticles.com/p/articles/mi_zdpcm/is_200411/ai_n7182425
[17] http://www.plyojump.com/hrp.html

CMST's BHR-1
[18] http://www.smh.com.au/articles/2002/12/30/1041196584677.html