On Human Behavioral Data Base and Humanoids

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Humanoids: What's next?

More toward Humans
More toward Robots

Eventually,
toward Human-Robot Communication

magic mirror

A. Murai, K. Kurosaki, K. Yamane, Y. Nakamura, "Computationally Fast Estimation of Muscle Tension for Realtime Bio-feedback," Proc. of 31st Annual International Conference of IEEE EMBS, September 4-6, 2009.

Magic Mirror: Dr. Wolfgang Sepp
Technology:
Akihiko Murai
Kosuke Kurosaki

Magic Mirror: Golf
Date: 2009.03

Magic Mirror: Jump
Date: 2009.03

Off-Line Analysis of Musculo-Skeletal System by sDIMS

WBA Super-Fly Class Champ: Mr. Nobuo Nashiro
Date: 2008.08
Place: Doshisha University
Analysis and Visualization: Akihiko Murai

Taichi Master: Mr. Jin You
Data: 2010.04.05
Place: Cyber Behavior Studio, University of Tokyo
Analysis and Visualization:
Ko Ayusawa, Yusuke Nakamura, Jun'ichi Ishikawa, Taku Kashiwagi

The Top Tap Dancer: Hirobo
Date: 2010.10.30
Place: Cyber Behavior Studio, University of Tokyo
Analysis and Visualization:
Ko Ayusawa, Yosuke Ikegami, Yusuke Nakamura, Yuki Ibuka, Jun'uchi Ishikawa, Taku Kashiwagi
Movie 1, Movie 2

Identification method

Identification with only Unactuated-Body dynamics

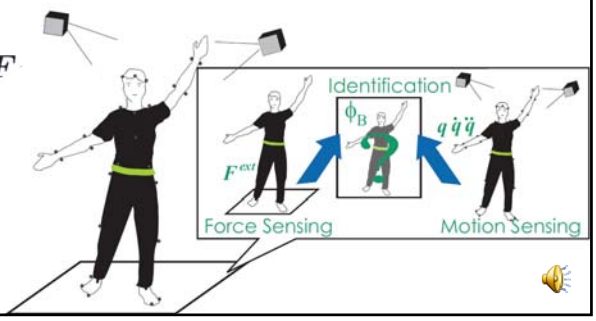
[Venture et al. (2008)]

$$\boldsymbol{Y}_B\boldsymbol{\phi}_B = \begin{bmatrix}\boldsymbol{Y}_{B1}\\ \boldsymbol{Y}_{B2}\end{bmatrix}\boldsymbol{\phi}_B = \begin{bmatrix}\boldsymbol{0}\\ \boldsymbol{\tau}\end{bmatrix} + \sum_{k=1}^{N_c}\begin{bmatrix}\boldsymbol{K}_{k1}\\ \boldsymbol{K}_{k2}\end{bmatrix}\boldsymbol{F}_k$$

regressor

base parameters (to identify)

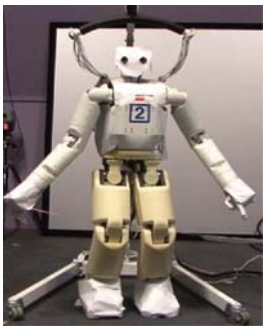
$$\boldsymbol{Y}_{B1}\boldsymbol{\phi}_B = \sum_{k=1}^{N_c}\boldsymbol{K}_{k1}\boldsymbol{F}$$



Identification of Humanoids

Physical consistent identification of Standard Inertial Parameters
Ko Ayusawa, Yoshihiko Nakamura
IFToMM-CISM Romansy2010, IEEE IROS2010.

Basa Parameter Identofication
Ko Ayusawa, Gentiane Venture and Yoshihiko Nakamura
IEEE Humanoids2008.

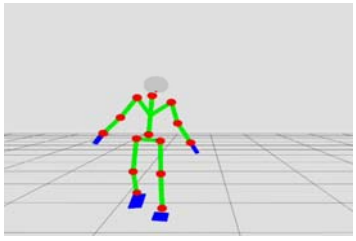


Number of joint	3 (neck) 1 (waist) 7 (each leg) 7 (each arm) 3 (each hand)
Sensors	gyro/accceleration sensor (in the upper body link) 6-axis force sensors (in both feet) encorders (in each joint)

- Using 33 links (Total 39 links)
- Motions used for identification
  - •Walking motion (backward, left-side, right-side)
    (Walking forward is used for cross validation)
  - •Left and right turning motion
  - •Left and right arm motion
  - •Head motion

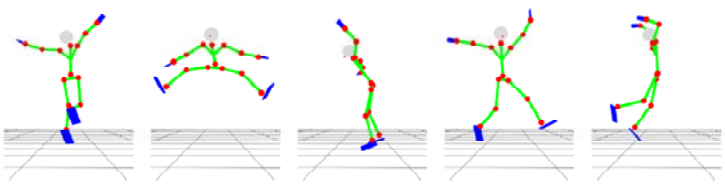
Application to a flying human

Ko Ayusawa, Gentiane Venture and Yoshihiko Nakamura, “Identification of Flying Humanoids and Humans.” IEEE ICRA2010.



34DOF human model

- Using motion data when the subject in the air（150 sec）
  + total body weight of the subject

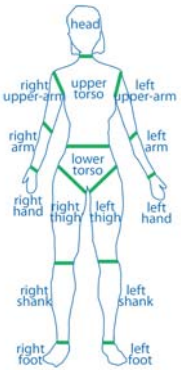


Realtime Visualization of Progress of Estimation

IEEE IROS2009 G. Venture, K. Ayusawa, Y. Nakamura

- Colored according to the relative standard deviation computed on the fly.
- Shake the bodies of poor estimation!
- Persistent Excitation Trajectories

15 links, 34 DOF



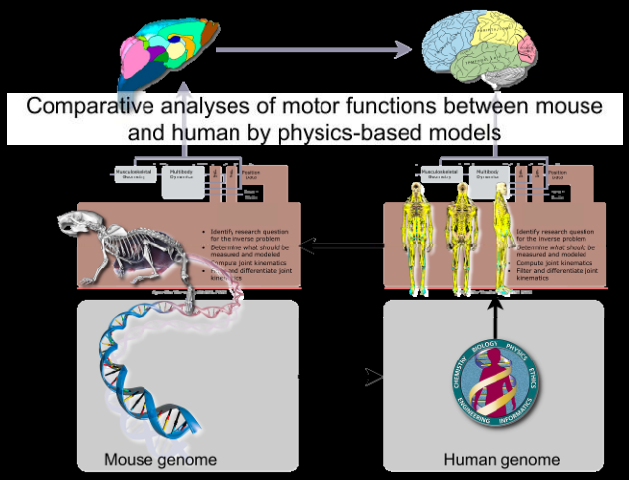
Satoshi Oota, Kazuyuki Mekada, Akihiko Murai, Yoshihiko Nakamura, Yuichi Obata, Atsushi Yoshiki:

"A new approach to analyze mutant specific gait patterns of mutant mice", Neuroscience 2009

Mutant Mice

A spontaneous mutant carrying the hugger (Bode, 1980; Sidman et al., 1997) allele (*hug*^{Rbrc}). Homozygous *hug/hug* mutant shows a queer gait pattern: a duck-like walking pattern (according to human perception), while heterozygous *hug/+* mice are normal.

Neuroethology
Bridge Genotype and Phenotype by Homology



A new paradigm of experimental neuromusculoskeletal studies

Homology?

Satoshi Oota, Atsushi Yoshiki, Hideo Yokota, Yuichi Obata, Yoshihiko Nakamura, Ryutaro Himeno: “Of Mice and Men: Biomechanical Modeling as a Tool to Translate Bone Biology Research into Clinical Practice,“ The 6th World Congress on Biomechanics, Singapole, August1-6, 2010.

(1) Morphing bones from human to mouse
based on feature points on the bones.

(2) Morphing muscles from human to mouse
based on the bone morphing

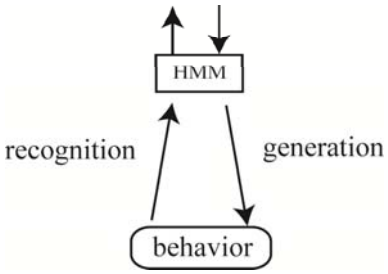
Studying geometrical morphology and evolutional morphology among the mammals.
Obtaining the initial setting of musculoskeletal network in a different mammal.

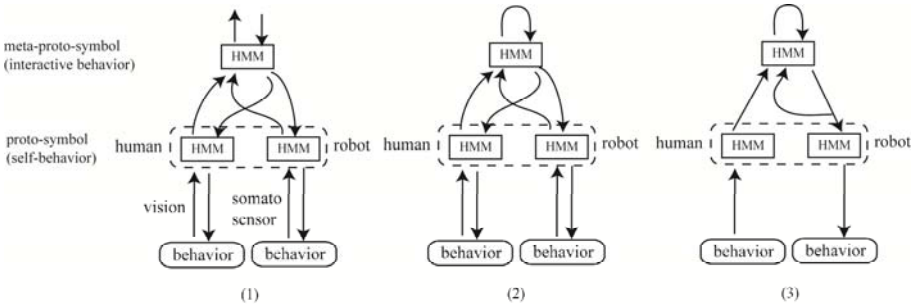
Semiotics and Linguistics

Mathematical Model of Mirror Neuron

Tetsunari Inamura, Yoshihiko Nakamura, Hideaki Ezaki and Iwaki Toshima, “Imitation and Primitive Symbol Acquisition of Humanoids by the Integrated Mimesis Loop,” IEEE International Conference on Robotics and Automation, Vol.4, pp.4208-4213, Seoul, Korea, May, 2001.

T. Inamura, I. Toshima, H. Tanie and Y. Nakamura："Embodied Symbol Emergence Based on Mimesis Theory," International Journal of Robotics Research, Vol.23, No.4/5, pp.363-378, 2004.





Mimetic Communication Hypothesis

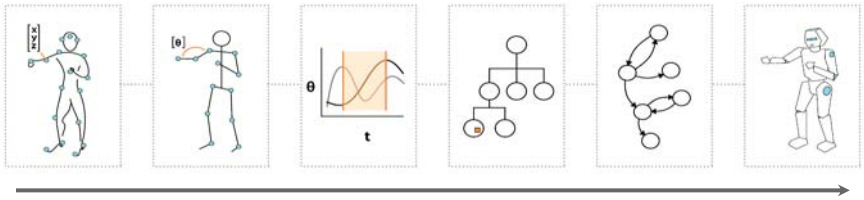
EXPO2005 NEDO Prototype Robot Exposition (2005.6.9-19)

W. Takano, K. Yamane, T. Sugihara, K. Yamamoto, and Y. Nakamura: “Primitive Communication based on Motion Recognition and Generation with Hierarchical Mimesis Model,” International Conference on Robotics and Automation, pp.3602-3609, 2006.

Mimetic Communication for Physical Human Robot Interaction (pHRI)

Dongheui Lee, Christian Ott, and Yoshihiko Nakamura: Mimetic Communication with Impedance Control for Physical Human-Robot Interaction, IEEE International Conference on Robotics and Automation, 2009.

Life-Long Learning



Capturing motion

Segmentation
Clustering

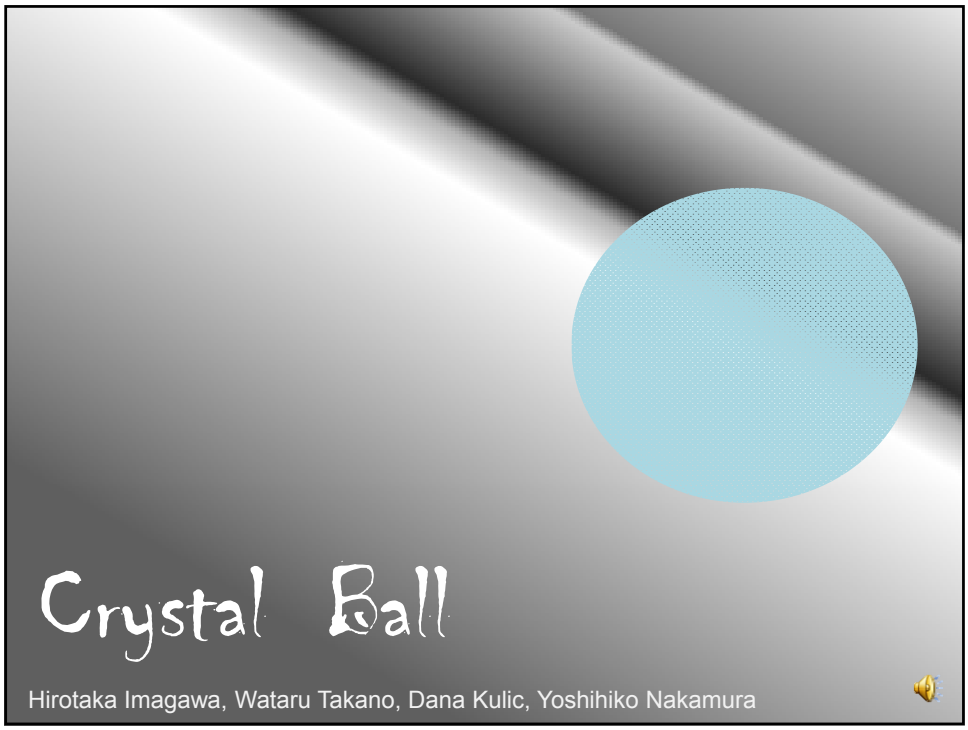
Learning
transition
network

Executing

Unsupervised Realtime Segmentation
Temporal Compression

Realtime Incremental Clustering
Spatial Compression

S. Janus and Y. Nakamura, IEEE ICAR 2005
D. Kulić and Y. Nakamura, IEEE IROS 2008
D. Kulić, W. Takano, Y. Nakamura IEEE ICRA 2008
D. Kulić, D. Lee, C. Ott, Y. Nakamura. IEEE Humanoids 2008


Crystal Ball
Hirotaka Imagawa, Wataru Takano, Dana Kulic, Yoshihiko Nakamura


Unsupervised Realtime Segmentation
Recognition in Transition Network
Crystal Ball
Hirotaka Imagawa, Wataru Takano, Dana Kulic, Yoshihiko Nakamura

CMU Motion Database (http://mocap.cs.cmu.edu)

Approximately 14 hours
56,727 motion patterns

W. Takano, H. Imagawa, Y. Nakamura, IFToMM-Japan 2010

Linguistics

Phonology
Morphology
Syntax
Semantics
Pragmatics

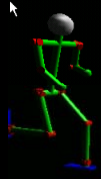
W. Takano and Y. Nakamura, "Integrating Whole Body Motion Primitives and Natural Language for Humanoid Robots", Proc. of IEEE-RAS International Conference on Humanoid Robots, pp.708-713, 2008.
W. Takano and Y. Nakamura, "Statistically Integrated Semiotics that Enables Mutual Inference Between Linguistic and Behavioral Symbols for Humanoid Robots," Proc. of IEEE International Conference on Robotics and Automation, 2009.
W.Takano and Y. Nakamura, "Incremental Learning of Integrated Semiotics Based on Linguistic and Behavioral Symbols," Proc. of IEEE/RSJ International Conference on Intelligent Robots and Systems, pp.2545-2550, 2009.

Use of word labels of behaviors (motion search)

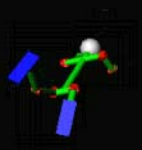
"left_swing run"

Use of word labels of behaviors (motion generation)

"left_swing run"



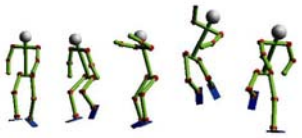
"diving stand_up right_
throw_pose standing"



Simple morphology system with behavioral symbols

The number of latent state in motion language model : 50
The number of proto symbol : 10 The number of words : 15
The number of word class : 5

start 選手 が 走る end
〈A player runs〉



start 選手 が 跳ぶ end
〈A player jumps〉

start 選手 が 捕球する end
〈A player catches〉

start 投手 が 投げる end
〈A pitcher throws〉

The computational time for searching a sentence is 3ms
on Xeon3.6GHz processor

Interpretation of Behaviors

Robot observes the motion and interprets the observation as sentences.

What's next?

Connecting Behaviorial and Linguistic Reasoning For Communication

1) read body sensation
2) build and grow system of symbols: spatiotemporal compression
3) communicate based on system of symbols
4) interface spoken language and system of symbols
5) communicate using spoken language (TBS)

Machine that Understand Human Body Sensation

1) Biological and medical applications
2) Deeper understanding for human-robot communication

special thanks to

WBA Super-Fly Class Champion: Mr. Nobuo Nashiro
Taichi-Master: Mr. Jin You
Tap-dancer: Hirobo

S. Oota, K. Mekada, Y. Obata, A. Yoshiki
RIKEN BRC, Tsukuba

K. Ayusawa, A. Blasdel, H. Esaki, Y. Fujita, S. Hamano, M. Hirashima, Y. Ibuka, Y. Ikegami, T. Imagawa, T. Inamura, J. Ishikawa, T. Jodan, H. Kadone, H. Kaminaga, M. Kanazawa, T. Kashiwagi, N. Kawabe, D. Kulic, H. Kunori, K. Kurosaki, D.H. Lee, A. Murai, Yusuke Nakamura, M. Otake, C. Ott, W. Sepp, T. Sugihara, I. Suzuki, W. Takano, H. Tanie, S. Takaya, H. Tanaka, I. Toshima, Y. Uchihara, K. Yamamoto, K. Yamane, C-H. Yi, G. Venture, and many more who are/were in *YNL @UT*