Transitioning humanoid robots from laboratory to home:

From 3D printing to AI-driven computation

Prof. Hironori Kasahara, IEEE Fellow, IPSJ Fellow
Senior Executive Vice President, Waseda University
IEEE Computer Society President 2018
URL: http://www.kasahara.cs.waseda.ac.jp/

1980 BS, 82 MS, 85 Ph.D. , Dept. EE, Waseda Univ.
1985 Visiting Scholar: U. of California, Berkeley, 1986 Assistant Prof, 1988 Associate Prof, Waseda
1989-90 Research Scholar: U. of Illinois, Urbana-Champaign, Center for Supercomputing R&D,
1997 Prof., 2004 Director, Advanced Multicore Research Institute, Waseda
2017member: the Engineering Academy of Japan (2020 Board）, Science Council of Japan
2018 IEEE Computer Society President, Senior Vice President for Reseach & IT, Waseda Univ.

<Committees in Societies and Government: 263>
IEEE Computer Society：President 2018, Executive Committee(2017-2019), BoG(2009-14),
Strategic Planning Committee Chair 2018, Multicore STC Chair (2012-), Japan Chair(2005-07),
IPSJ Chair: HG for Magazine. & J. Edit, Sig. on ARC.
【METI/NEDO】Project Leaders: Multicore for Consumer Electronics, Advanced Parallelizing
Compiler, and Green Computing, Chair: Computer Strategy Committee
【Cabinet Office】CSTP Supercomputer Strategic ICT PT, Japan Prize Selection Committees, etc.
【MEXT】Info. Sci. & Tech. Committee, Supercomputers (Earth Simulator, HPCI Promo., Next Gen.
Supercomputer K) Committees, JST Moonshot Project G3 Robot & AI Vice Chair,
【COCN】Board Member in Council of Competitiveness Nippon, etc.

<Research Accomplishment>
Reviewed Papers: 221,   Invited Talks: 190,
Granted Patents: 54 (Japan, US, GB, China),
Articles in News Papers, Web News, TV etc.: 625

<AWARD>
1987 IFAC World Congress Young Author Prize
1997 IPSJ Sakai Special Research Award,
2005 STARC Academia-Industry Research Award,
2008 LSI of the Year Second Prize,
2008 Intel Asia Academic Forum Best Research Award,
2010 IEEE CS Golden Core Member Award
2014 Minister of Edu., Sci. & Tech. Research Prize
2015 IPSJ Fellow, 2017 IEEE Fellow, Eta Kappa Nu
2019 Spirit of IEEE Computer Society Award,
2020 IPSJ Contribution Award

早稲田大学

USA President Bill Clinton

USA Ambassador Caroline Kennedy

Chinese President Hu Jintao

WASEDA University

Tokyo - Attractive Location

Shinjuku-ku, Tokyo, Japan

Takadanobaba

UENO
AKIHABARA
WASEDA
SHINJUKU
TOKYO
SHIBUYA

KITA-KYUSHU CAMPUS

TOKYO

TOKYO: 7 CAMPUSES · SAITAMA: 2 CAMPUSES

#1 MICHELIN-STARRED RESTAURANTS (TRIPADVISOR)
#3 BEST STUDENT CITIES RANKING (QS BEST STUDENT CITIES 2016)
#1 GLOBAL CITY RANKING (AT KEARNEY 2014)
#1 HOSPITABLE CITY (TRIPADVISOR 2014)
#1 PUBLIC TRANSPORTATION, HELPFUL LOCALS, SAFETY, CLEANLINESS (TRIPADVISOR 2014)

Tokyo, Japan

Microsoft: Honorable Dr. Bill Gates

British Prime Minister Boris Johnson

《 1922
Visit by physicist Albert Einstein to Waseda University

《 1974
Archaeological excavation of the Malkata site

1882 》
Okuma Shigenobu founded Tokyo Senmon Gakko (College)

1928 》
Japan's first gold medalist

The "Group of Four" who contributed to the development of Waseda University

1940
"Visas for life" from diplomat Chiune Sugihara

1993 》
Visit to Waseda University by then U.S. President Bill Clinton

1956 》
The beginnings of the Ishibashi Cabinet, first alumnus of Waseda to become Prime Minister

2007 》
125th founding anniversary – Toward the "second establishment" of the university

早稲田大学創立125周年

1903 》
Start of the Waseda-Keio baseball match (Sokeisen)

《 1962
Robert Kennedy attends student debate

《 2012
Formulation of Waseda Vision 150

TGU

WASEDA UNIVERSITY

Number of International Students

7,942[*] from **125**[*] countries and territories
(Undergraduate and Graduate)

Alumni CEOs in Japan

10,606

8 Prime Ministers

Founder Shigenobu OKUMA

Graduate Employability

#1 in private university of Japan
(#2 in Japan, #27 in the world)
QS Graduate Employability Rankings 2019

ALUMNI [卒業生]	
630,000	

PARTNER INSTITUTIONS [協定大学・機関]	
848 (93 countries)	

FACULTY [教員]	ENROLLMENT [学生数]	UNDERGRADUATE STUDENTS [学部生]	GRADUATE STUDENTS [大学院生]
5,468	49,436	41,051	8,385

NUMBER OF BOOKS [図書館蔵書]
5,800,000

Hiroshi YAMAUCHI — Nintendo
Masaru IBUKA — SONY
Tadashi YANAI — UNIQLO MADE FOR ALL

mercari · HEROZ JAPAN · LINE

Prime Ministers

8th Shigenobu Okuma
17th Shigenobu Okuma
55th Tanzan Ishibashi
74th Noboru Takeshita
76th Toshiki Kaifu
84th Keizo Obuchi
85th Yoshiro Mori
91st Yasuo Fukuda
95th Yoshihiko Noda

Business Leaders
Founders of global companies

Sony
Samsung
Casio
LOTTE

Business Leaders
CEOs of global companies

ANA (All Nippon Airways)
HONDA
Nintendo
UNIQLO
Shiseido
Nomura Securities Co., Ltd.
Tokio Marine & Nichido Fire Insurance Co., Ltd.
Olympus Corporation

Aiji TANAKA
President
International Political Science Association (IPSA)
President 2016

Hironori KASAHARA
Senior Executive Vice President
IEEE Computer Society President 2018. The first president from outside USA and Canada in 72 years CS history. CS has 84,000 members from 168 countries.

Toshio FUKUDA
The University Professor Waseda, Waseda Alumnus, Prof. Emeritus Nagoya Univ., Prof. Meijo Univ.
IEEE President 2020. The first from Asia in 135 years history.
IEEE has 420,000 members.

Haruki MURAKAMI

Hirokazu KOREEDA

Yuzuru HANYU

S. ARAKAWA

Daiya SETO

Mighty Atom (鉄腕アトム, Tetsuwan Atomu) A Humanoid Having Human Emotion

MANGA published by Osamu Tezuka from 1952 to 1968. TV Anime series Astro Boy was started in 1963.
Astro Boy was created at Takadanobaba, Hometown of Waseda Univ.,   in original Manga.

https://en.wikipedia.org/wiki/Astro_Boy
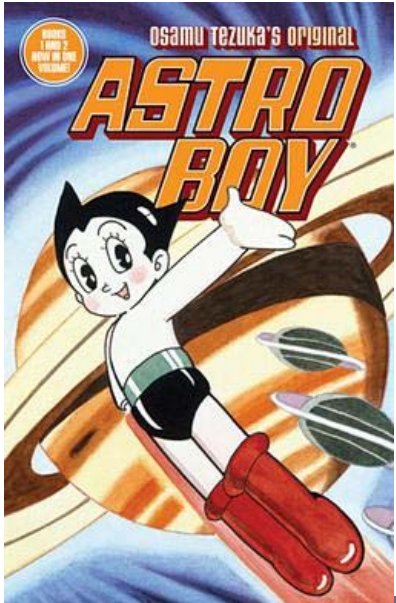
The cover for Astro Boy volume 1 and 2 compilation by Dark Horse Comics.

WASEDA BEAR & ASTRO BOY   ©Tezuka Productions/WASEDA University

https://www.waseda.jp/top/news/68652

©Tezuka Productions

Waseda U Flag

Mr. Tezuka drew in1964 when Tokyo Olympics was held.

Humanoid Robots Led by Prof. Ichiro Kato, Waseda Univ. Father of Japanese Humanoid

He started development of Humanoid late 1960 believing each family would have My Robot like My Car

Conversation System with human:
Prof. Katsuhiko Shirai (EE, later CSE):
Waseda U President 2002-2010

Human Face Recognition System:
Prof. Kan Oteru (Applied Physics)

WABOT-1 (1973)

Conversation:
Prof. Katsuhiko Shirai (EE, later CSE):
Face Recognition:
Prof. Kan Oteru (Applied Physics)

Fingering from Music Score & Computer :
Prof. Seinosuke Narita (EE, later CSE):

WABOT-2 (1984)

Prof. Ichiro Kato (1925-1994)
He was Dean of School of Sci. & Eng.
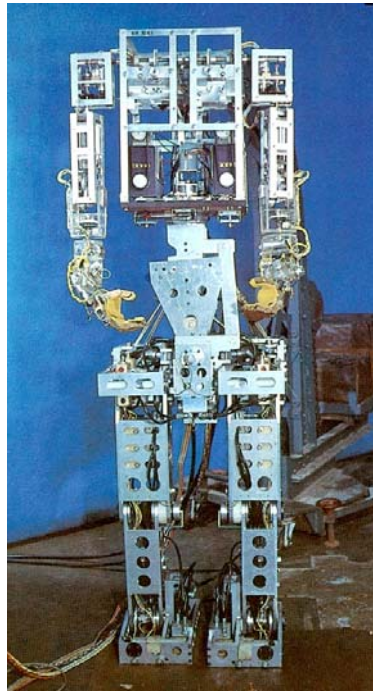
Tsukuba Expo 1985 Playing with Orchestra

Current Robotics Researchers in Waseda University

Professors	Subjects
Jun OHYA	Robot Vision
Mitsuo UMEZU	Artificial Organ
Atsuo TAKANISHI	Biped Humanoid, Disaster Robot: Robot Society of Japan Ex-President
Tetsunori KOBAYASHI	Conversation System
Shigeki SUGANO	Human Symbiotic Robot, HRI: SICE Ex-President, Senior Dean of School of Sci. & Eng.
Tomoyuki MIYASHITA	Space Robots, Robot Design
Tetsuya OGATA	Robot and AI (Deep Learning)
Hideyuki SAWADA	Chemical Robot, Recognition
Hiroyasu IWATA	Medical & Welfare Robot
Shigeru UESUGI	Human Interface
Shinjiro UMEZU	Micro-Nano Robot, Bio Robot
Eiji IWASE	Micro-Nano Mechanism, Material
Hiroyuki ISHII	Field and Distributed Robotics

Prof. Takanishi's Walking, Flute and Sax Playing, Conducting, Emotion Expression, Person Carrying Robots

WABIAN-2R Walking Robot

WF-4's Flute Play:
The Flight of the Bumble-Bee
(Rimsky-Korsakov)
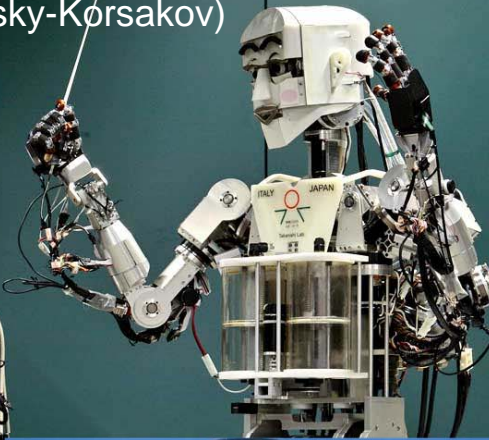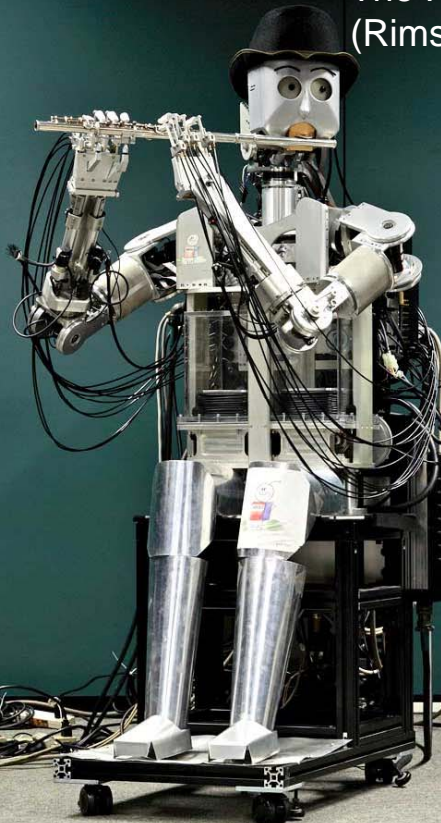
Happiness

Emotion Expression Humanoid:
Demos of EYE-Chan

WL-16 Can Carry Person up to 80[kg]

More Human-like Walking by WABIAN-2R with a 50cm-Step by Prof. Takanishi
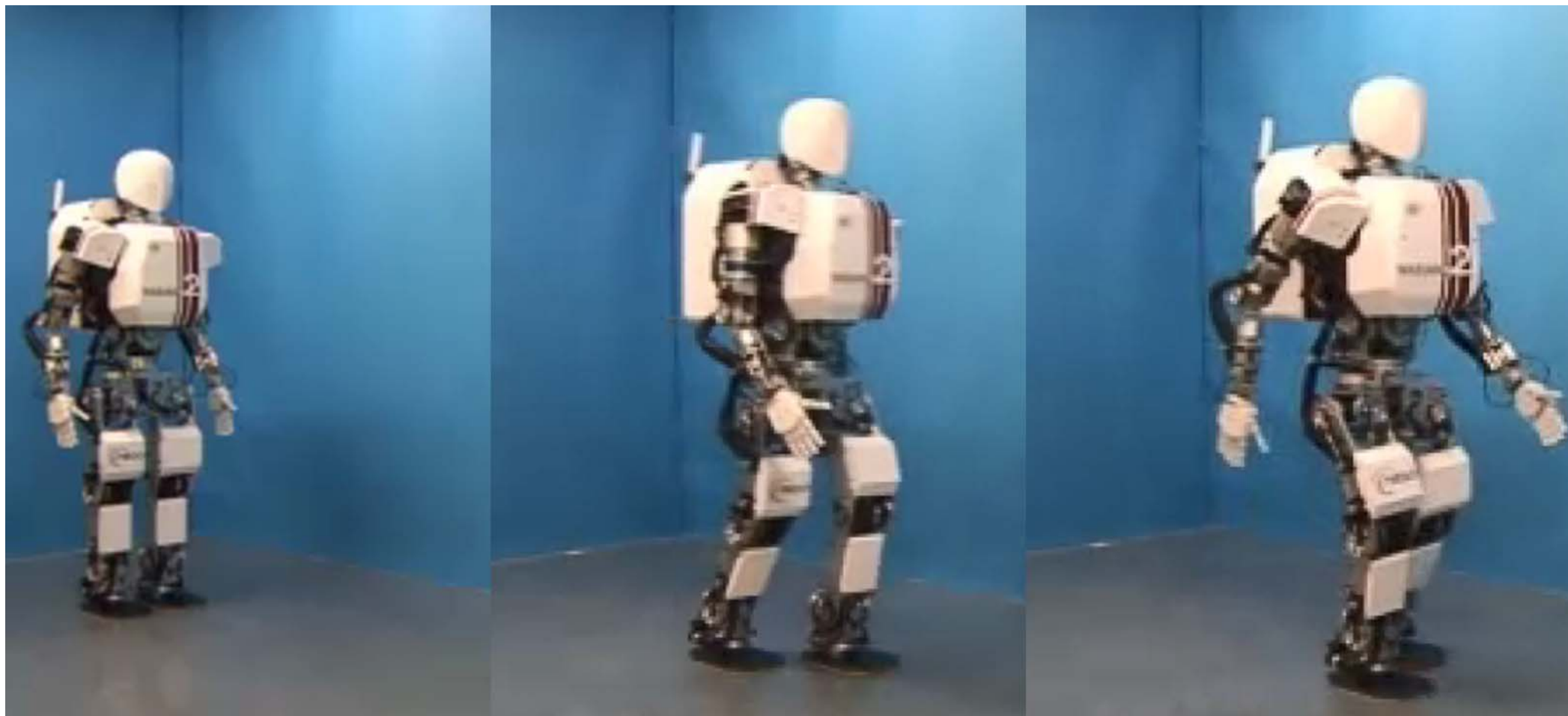
0.50[m/step], 0.96[s/step]

Baby Robot for Emergency Medical Training

- Measurement of airway management motion

(上顎圧力) Upper jaw pressure sensor	(喉頭圧力) Larynx pressure sensor		(チューブ位置) Tube position sensor		(食道挿管) Esophageal intubation sensor		(換気圧) Ventilation pressure sensor	
	Left: 3ch	Right: 3ch	Left: 5ch	Right: 5ch	Left: 1ch	Right: 1ch	Left lung: 1ch	
							Right lung: 1ch	
							Stomach: 1ch	

520

85

Head IMU	Oral camera	Microcontroller	Wireless communication module	Battery	Abdomen IMU
		A/D converter / Sensor controller			

TWIns :
Tokyo Women's Medical Univ. – Waseda Univ. Institution for Advanced Biomedical Sciences

Robotics in Waseda University 1999-2015
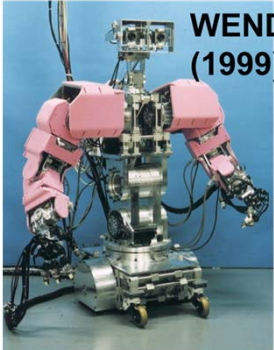
WENDY
(1999)

WABIAN-RV
(2001)

2000 : Humanoid Institute
2001 : WABOT-HOUSE Laboratory

2004: WABOT-HOUSE
Structured environment

Prof. Atsuo TAKANISHI
Dept. Modern
Mechanical Eng.

Surgical Robot

WABIAN-II (2005)
For More Natural
Two Legs Walking
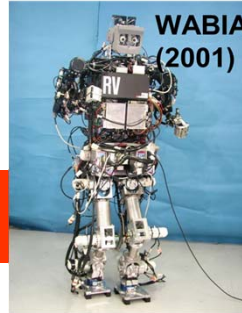
2005 : WABIAN-II

Biped Robot

2007 : TWENDY-ONE

Human Symbiotic Robot

TWENDY-ONE
(2007)
For Elderly Care
Safety Robot

Prof. Shigeki SUGANO
Dept. Modern
Mechanical Eng.

2015 : Future Robotics Organization

ROBITA

2009: SCHEMA

Conversation Robot

Prof. Tetsunori KOBAYASHI
Dept. Computer Sci. & Eng.

2015: Octopus

Disaster Robot

Prof. Ogata's Deep predictive learning

Collecting the data of human operation (**skill**)
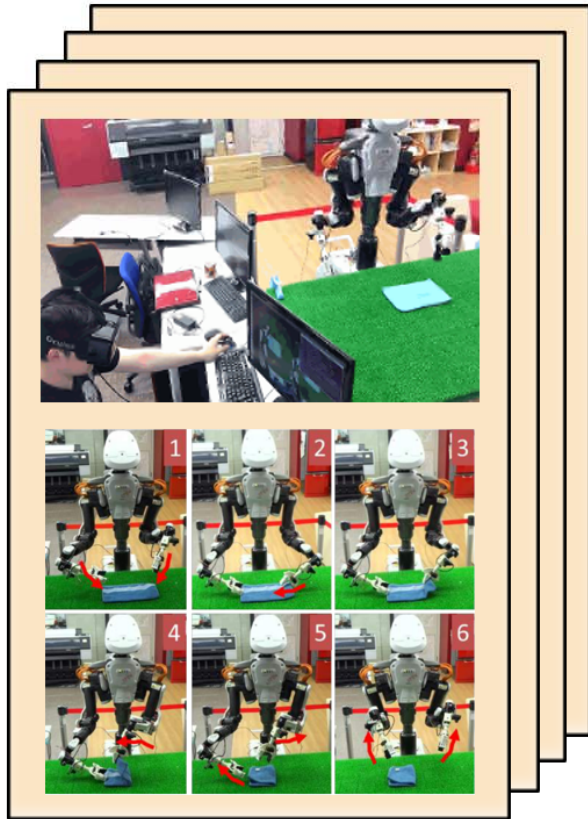
Subjective world model for **real time** prediction of sensory-motor values

Input of joint angles → Deep Learning (LSTM, MTRNN) → Prediction of joint angles

Camera Image → Deep Convolutional Encoder

Deep Convolutional Decoder

OutSourceImage(Camera)

TDNNOutImage(Predict) — Predicted Image

Association result (dash line : target data)

Joint angle — Value (normalized)

Time step
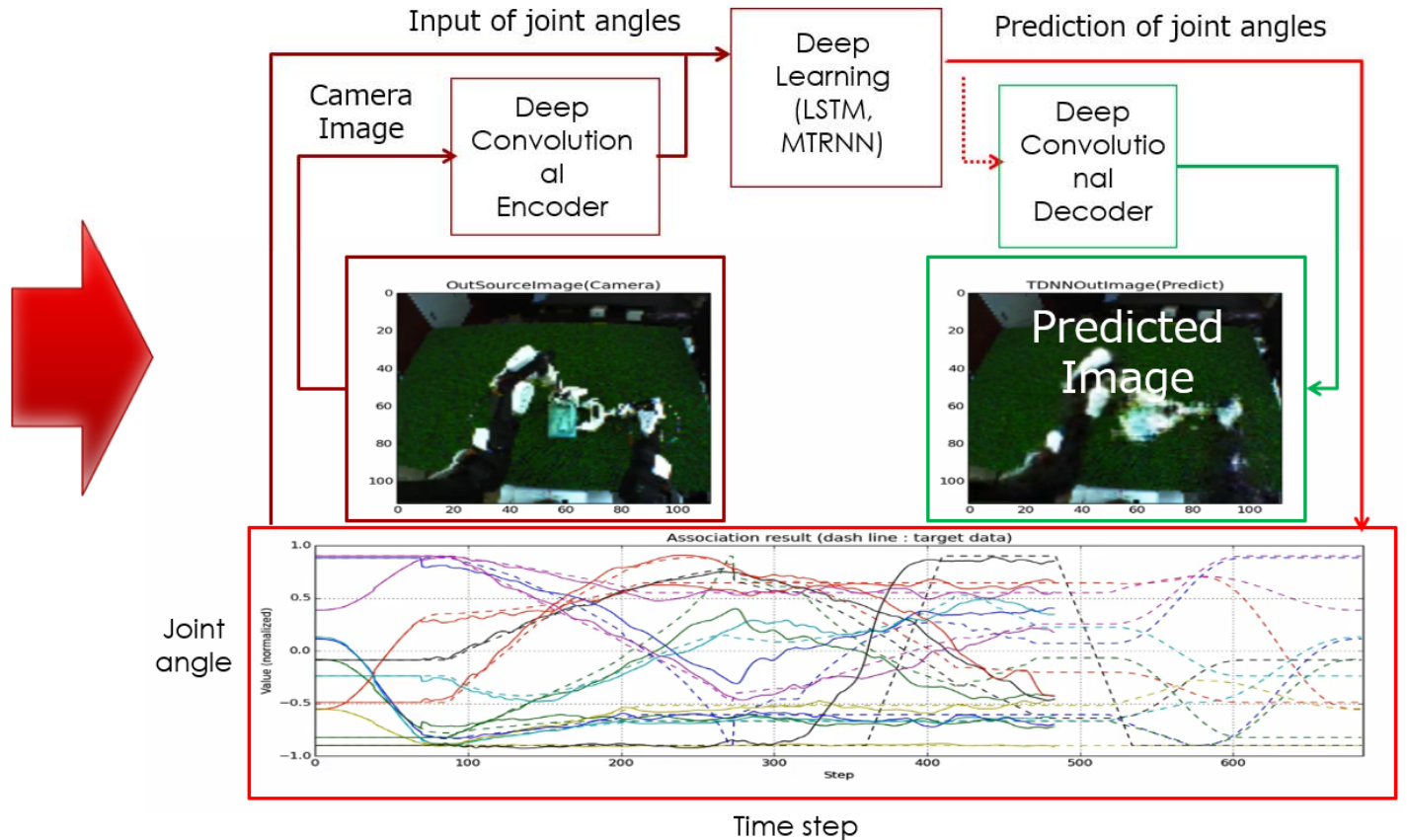
Demonstration of Deep Prediction Learning

Based on the concept of "**Embodied Intelligence**"

- ☐ **Repeatable and quick folding motion for the untrained positions and objects**

- ☐ **Less than a hundred trails with the limited object variations**
  IEEE RA Letters, 2016., ICRA2017 etc.

⬇

Experience based robotics
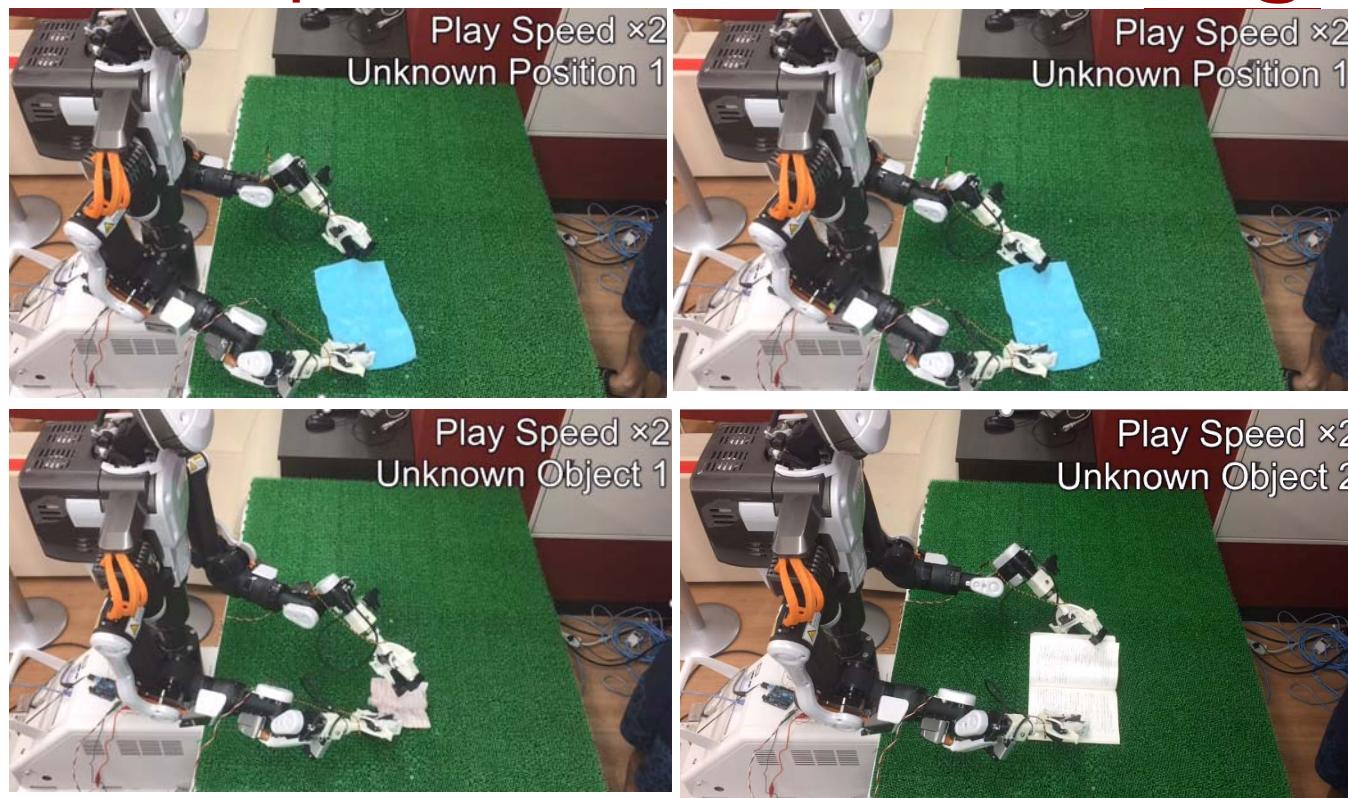
Folding motion (Soft joints in wrist parts)

Cebit 2017, CEATEC2017, iRex2017

AIST | AIRC | ◆

Hironori Kasahara has started collaboration with Wabot Group and research of hard-realtime Control and Simulation since 1982.

H. Kasahara, S. Narita, "Parallel Processing of Robot Arm Control Computation on a Multimicroprocessor System", IEEE Journal of Robotics and Automation, Vol. RA-1, No. 2, Jun. 1985.

H. Kasahara, H. Fujii, M. Iwata, "Parallel Processing of Robot Motion Simulation", Proc. IFAC 10th World Congress, pp.329-336, Jul. 1987. "IFAC World Congress Young Author Prize", 1987.

Engine Control by multicore with Denso

Though so far parallel processing of the engine control on multicore has been very difficult, Denso and Waseda succeeded 1.95 times speedup on 2core V850 multicore processor.

➢ Hard real-time automobile engine control by multicore using local memories

➢ Millions of lines C codes consisting conditional branches and basic blocks

ECUモデル

1.95

1

| 1 core | 2 cores |
| 逐次 | 並列化 |

13

OSCAR Compile Flow for Simulink Applications

Simulink model

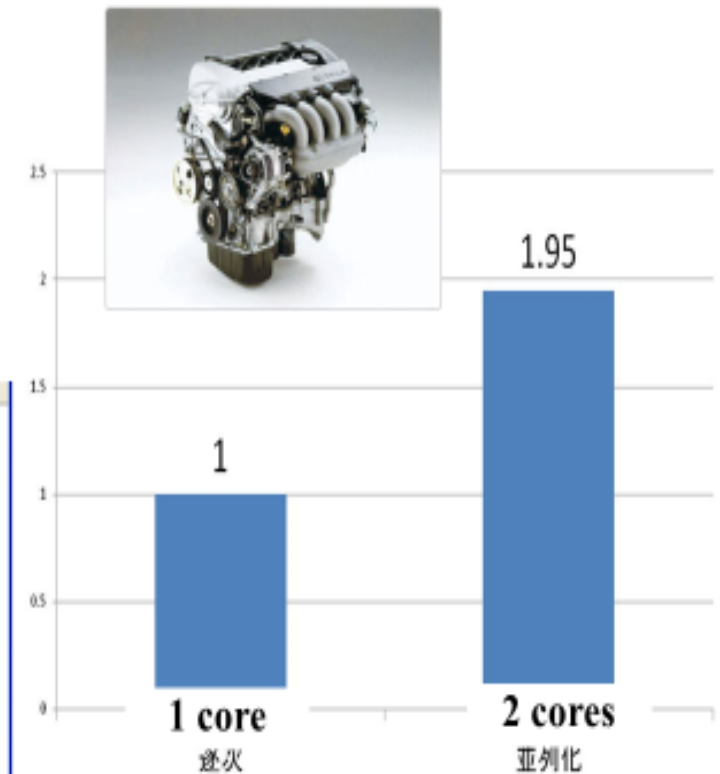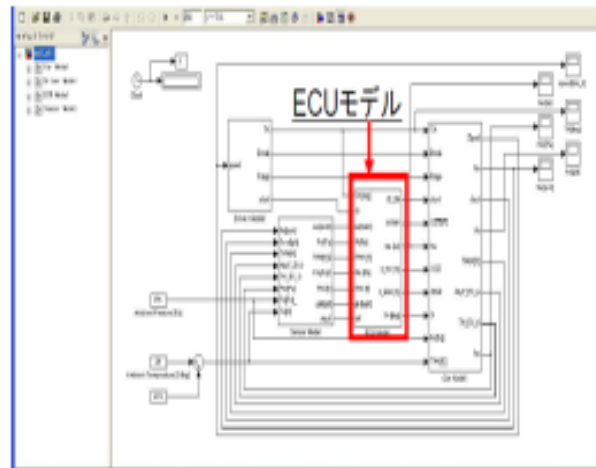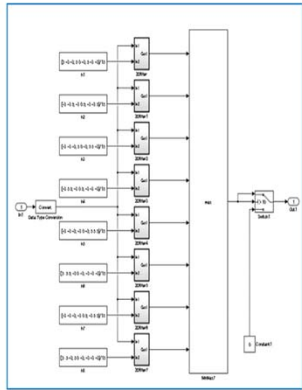Generate C code using Embedded Coder

C code

```
/* Model step function */
void VesselExtraction_step(void)
{
  int32_T i;
  real_T u0;

  /* DataTypeConversion: '<S1>/Data Type Conversion' incorporates:
   *  Inport: '<Root>/In1'
   */
  for (i = 0; i < 16384; i++) {
    VesselExtraction_B.DataTypeConversion[i] = VesselExtraction_U.In1[i];
  }
  /* End of DataTypeConversion: '<S1>/Data Type Conversion' */

  /* Outputs for Atomic SubSystem: '<S1>/2DFilter' */

  /* Constant: '<S1>/h1' */
  VesselExtraction_Dfilter(VesselExtraction_B.DataTypeConversion,
    VesselExtraction_P.h1_Value, &VesselExtraction_B.Dfilter,
    (P_Dfilter_VesselExtraction_T *)&VesselExtraction_P.Dfilter);

  /* End of Outputs for SubSystem: '<S1>/2DFilter' */

  /* Outputs for Atomic SubSystem: '<S1>/2DFilter1' */

  /* Constant: '<S1>/h2' */
  VesselExtraction_Dfilter(VesselExtraction_B.DataTypeConversion,
    VesselExtraction_P.h2_Value, &VesselExtraction_B.Dfilter1,
    (P_Dfilter_VesselExtraction_T *)&VesselExtraction_P.Dfilter1);
```
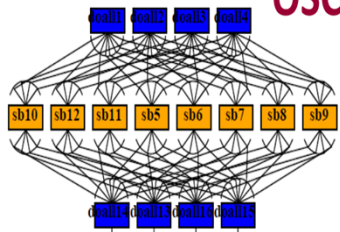
OSCAR Compiler


```
void VesselExtraction_step ( )
{
    int thr1 ;
    int thr2 ;
    int thr3 ;
    {
        oscar_thread_create ( & thr1 ,
            thread_function_001 , (void*)1 ) ;
        oscar_thread_create ( & thr2 ,
            thread_function_002 , (void*)2 ) ;
        oscar_thread_create ( & thr3 ,
            thread_function_003 , (void*)3 ) ;

        VesselExtraction_step_PE0 ( ) ;

        oscar_thread_join ( thr1 ) ;
        oscar_thread_join ( thr2 ) ;
        oscar_thread_join ( thr3 ) ;
```

```
void thread_function_001 ( void )
{
    VesselExtraction_step_PE1 ( ) ;
}
```

(1) Generate MTG
→ Parallelism

(2) Generate gantt chart
→ Scheduling in a multicore

(3) Generate parallelized C code using the OSCAR API
→ Multiplatform execution (Intel, ARM and SH etc)

Speedups of MATLAB/Simulink Image Processing on Various 4core Multicores
(Intel Xeon, ARM Cortex A15 and Renesas SH4A)
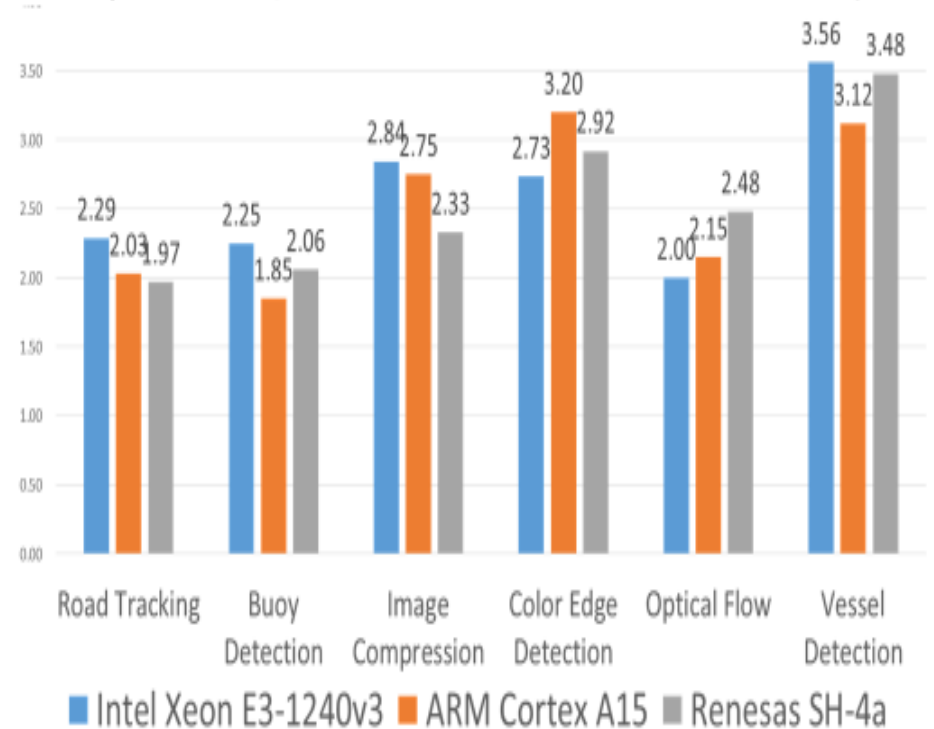
Demo of NEDO Green Multicore Processor for Real Time Consumer Electronics at Council of Science and Engineering Policy on April 10, 2008

http://www8.cao.go.jp/cstp/gaiyo/honkaigi/74index.html

第74回総合科学技術会議 【平成20年4月10日】
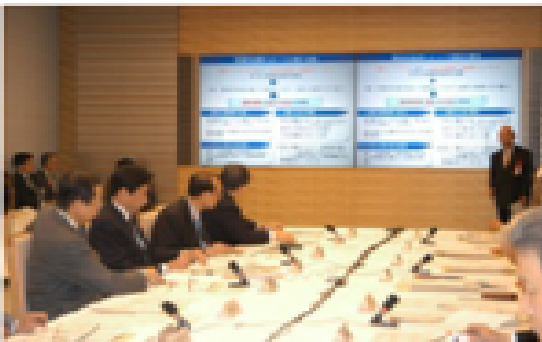
第74回総合科学技術会議の様子(1)

第74回総合科学技術会議の様子(2)

第74回総合科学技術会議の様子(3)

第74回総合科学技術会議の様子(4)

Codesign of Compiler and Multiprocessor Architecture since 1985

4 core multicore RP1 (2007), 8 core multicore RP2 (2008) and 15 core Heterogeneous multicore RPX (2010) developed in NEDO Projects with Hitachi and Renesas

Prime Minister FUKUDA is touching our multicore chip during execution.

15

Power Reduction of MPEG2 Decoding to 1/4 on 8 Core Homogeneous Multicore RP-2 by OSCAR Parallelizing Compiler

MPEG2 Decoding with 8 CPU cores
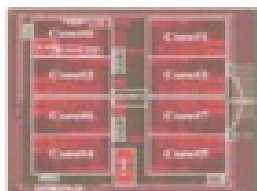
Without Power Control
（Voltage : 1.4V)
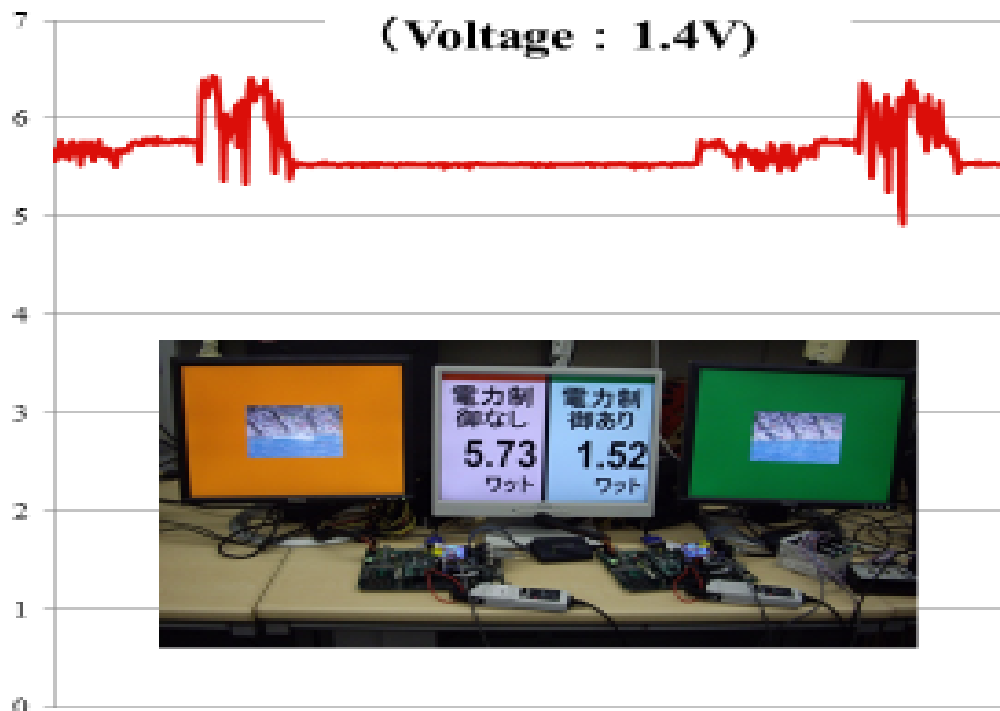
With Power Control
（Frequency,
Resume Standby:
Power shutdown &
Voltage lowering 1.4V-1.0V)
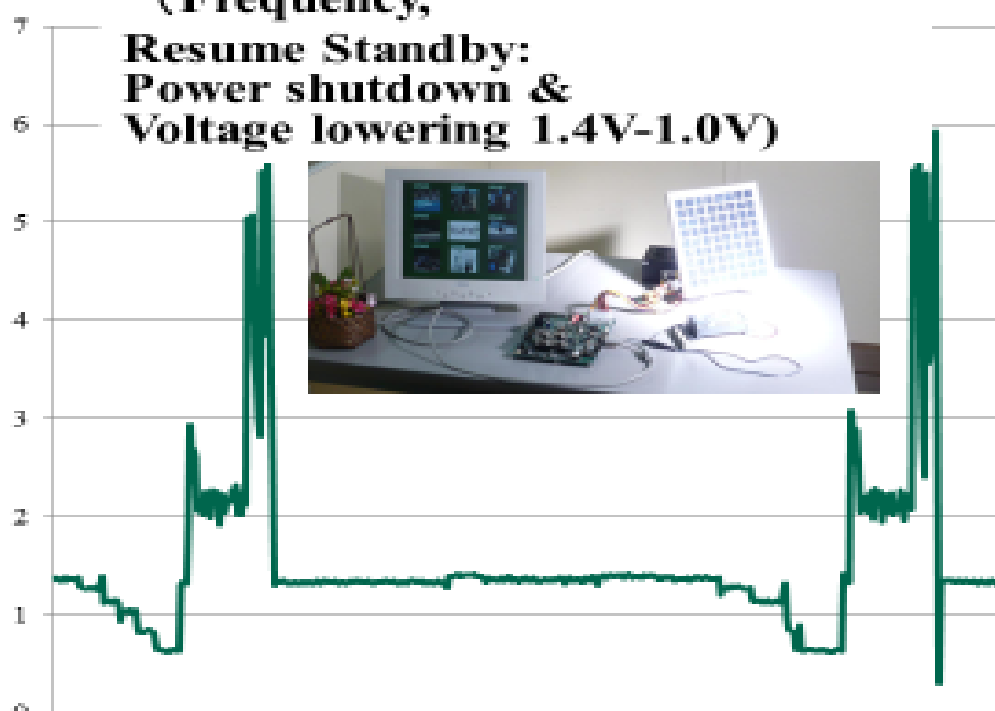
Avg. Power
5.73 [W]

73.5% Power Reduction

Avg. Power
1.52 [W]

Patents related with OSCAR Parallelizing Compiler & Hardware

58 international patents in USA, UK, China, Japan to improve effective performance, cost-performance and software productivity and reduce power

High Performance & Low Power

1) Multigrain Parallelization for Embedded and Heterogeneous Multicores & Hardware Supports (Synchronization)

coarse-grain parallelism among loops, subroutines & basic blocks among statements in addition to loop parallelism

2) Data Localization:
Cache & Local Memory Optimization

- Automatic data management for distributed shared memory, cache and local memory
- Software Cache Coherent Control
- Data Transfer Controller
- Data transfer overlapping using DMA hardware & its compiler

3) Automatic Power Reduction HW&SW

- Reduction of consumed power by compiler control DVFS and Power gating with hardware supports for Carbon Neutral.
- Accelerator See right figure
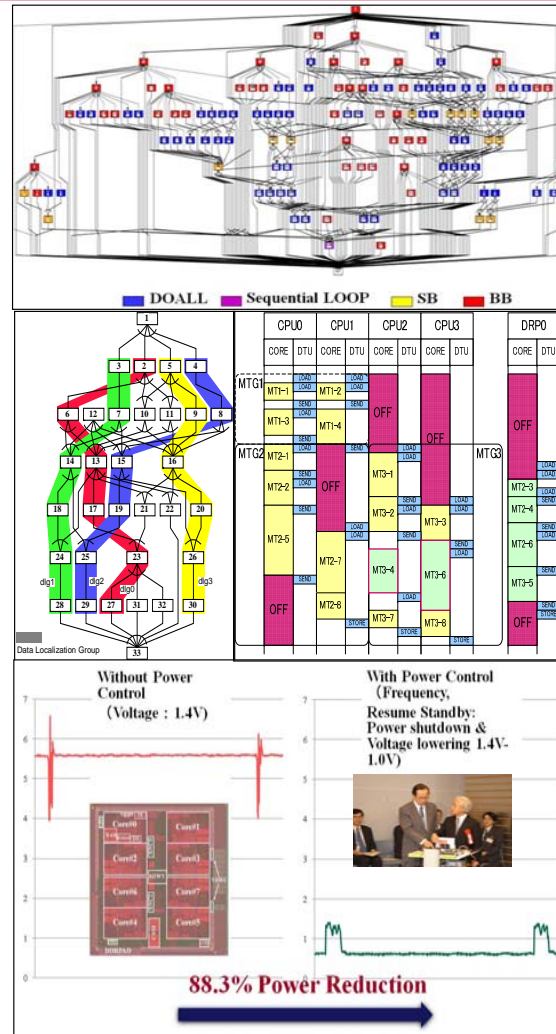
Green Accelerator

can be attached to any processor cores, RISCV, arm, Infineon Renesas, AMD, Intel, etc, without instruction extensions.

➤ It works with automatic local memory management and power reduction control by OSCAR Automatic vectorizing & parallelizing compiler
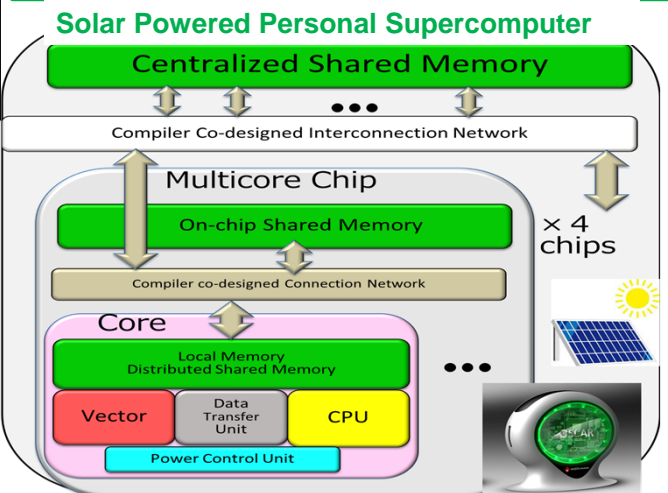
DOALL — Sequential LOOP — SB — BB

Without Power Control (Voltage : 1.4V)

With Power Control (Frequency, Resume Standby: Power shutdown & Voltage lowering 1.4V-1.0V)

88.3% Power Reduction

Solar Powered Personal Supercomputer

IEEE Computer Society

Bjarne Stroustrup: Morgan Stanley & Columbia Univ.
2018 IEEE Computer Society Computer Pioneer Award
IEEE COMPSAC2018 Keynote & Award Ceremony

July 26, 2018, Keynote,
Hitotsubashi Hall

July 25, 2018 Award Ceremony
Rihga Royal Hotel Tokyo

IEEE COMPUTER SOCIETY 2020 BY THE NUMBERS

225,000 COMMUNITY MEMBERS

CCF 中国计算机大会
China National Computer Congress
2018年10月25-27日 · 杭州

CNCC2018

•84,000+ members
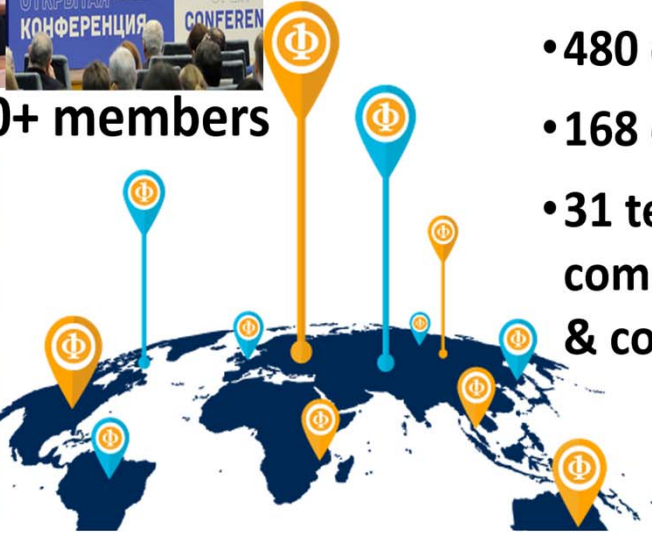
•480 chapters

•168 countries

•31 technical committees & councils

12 MAGAZINES
25 TRANSACTIONS/JOURNALS
810,000 ARTICLES IN THE CS DIGITAL LIBRARY

$100,000 AWARDS AND SCHOLARSHIPS

$3,000,000 FREE CONTENT DELIVERED IN THE WAKE OF COVID-19 VIA CONFERENCES, DIGITAL LIBRARY ACCESS, EDUCATIONAL COURSES, AND WEBINARS.

11 NEW STANDARDS

251 ACTIVE STANDARDS

VOLUNTEERS 9,000
COMMITTEES 679
MEETINGS 2,040

ACM/IEEE SC (SuperComputing) 19, Denver, Nov.17-22, 2019

Cornel Univ. Prof. Steven Squyres: Mars Exploration, Caltech. Dr. Katie Bouman:Visualization of Blackhole

https://www8.cao.go.jp/cstp/english/moonshot/sub3_en.html

Cabinet Office

Moonshot Goal #3

Realization of AI robots that autonomously learn, adapt to their environment, evolve in intelligence and act alongside human beings, by 2050.

Target of Moonshot Goal

- Development of AI robots that humans feel comfortable with, have physical abilities equivalent to or greater than humans, and grow in harmony with human life, by 2050.

- Development of AI robots that behave well with humans under certain conditions, and allow over 90% of people to feel comfortable with them, by 2030.

- Development of an automated AI robot system that aims to discover impactful scientific principles and solutions, by thinking and acting in the field of natural science, by 2050.

- Development of an automated AI robot system that aims to support the process of discovery for scientific principles and solutions to specific problems by 2030.

- Development of AI robots that autonomously make judgements and act in environments where it is difficult for humans to act by 2050.

- Development of AI robots that operate unattended under human supervision in specific circumstances by 2030.

20

AIREC (AI-driven Robot for Embrace and Care) Led by Prof. Sugano
Supported by Japanese Government "Moonshot" Project from 2020

caring sick persons

helping remote diagnosis

helping house business

Universal Smart Robot cares Family's Life-time from baby shitting to elderly care as a Family member.

caring elderly persons

caring children

house keeping

Exhibition Booth: Waseda U leading Researchers Incl. Robotics & Industry

Invited Speakers: International University, Society, Industry, Government

Opening
- Waseda U President: Aiji Tanaka
- aseda U Executive Committee Chair & SEVP: Hironori Kasahara
- MEXT Deputy Director General Mr. Susumu Kajiwara
- METI Deputy Director General Mr. Takahiro Hagiwara

Distinguished Invite Speakers
- VP Keidanren, Chairman NTT Mr. Hiromachi Shinohara
- IEEE President 2020 The Professor, Waseda Toshio Fukuda
- CISCO Asia, Pacific &China President Dave West

Distinguished Invite Speakers
- University of Oxford Vice Chancellor Louise Richardson
- Chairman Keizaidouyukai CEO Sompo Holdings Kengo Sakurada
- Founder & CEO Mercari Shintaro Yamada
- Founder & Partner of Kauffman Fellows & Sozo Venture Phil Wickham
- Y Combinator Partner

Green Computing Research Organization 10th Anniversary Symposium

Waseda & Related University Venture Pitch and Discussion with Silicon Valley Fund & Accelerator

Oxford-Waseda Computer Science Symposium

Waseda Research Innovation Center

Waseda Open Innovation Ecosystem

Waseda University

High added-value products and services

Research revitalization

- Participation of graduate students for Collaboration :
  - Increase PhD students with monetary supports
  - Increase top journal & conference papers & patents solving difficult problems from social needs
  - Motivate Professors and Researchers with incentives: reward, reduced lecture hours, space

Promote industry-academia cooperation

- **Support collaboration with industry**
  - Build teams for satisfying needs from Industry

One-stop support desk
  - Introduce university seed technologies (PR)
  - Matching of succeeded and new Ventures
  - Meeting of Industry, Ventures, Researchers & students

WoI Forum on March 10 every year
  - Contract support with Industry: IP & Budget Estimation
  - Student Agreement support (IPs and NDAs)
- **Patent Support**
  - Help acquire Intellectual Property through-out patent filing and examining to minimize researchers' loads
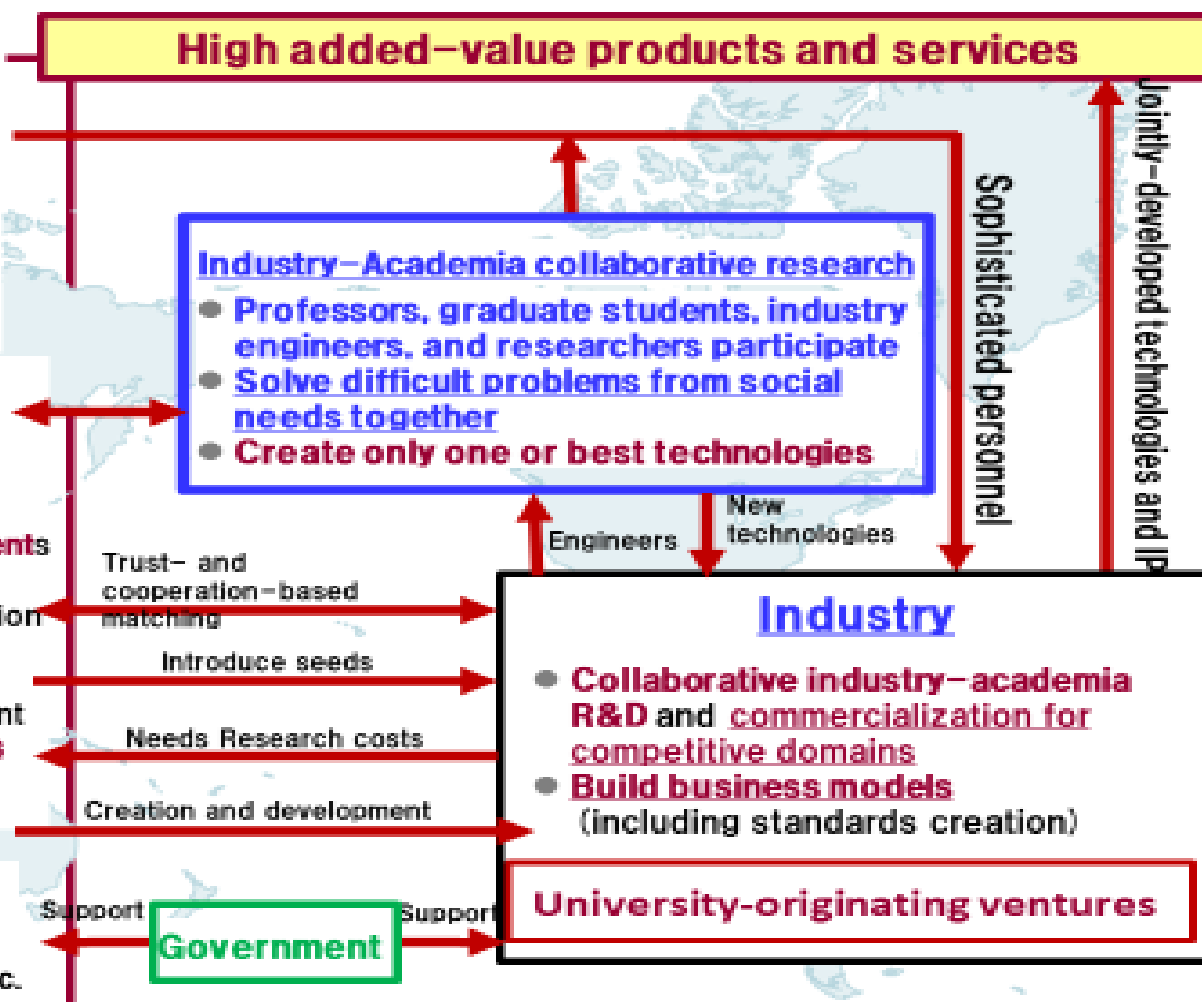 - Help utilize intellectual property: Licensing
- Research ethics course support

Venture startup and acceleration

- Introduce venture funds and teams including management, accounting, legal specialist
- University IP licensing by Cash, Stock, etc.
- Acceleration/Value-Up support: Customer matching etc.

Industry-Academia collaborative research

- Professors, graduate students, industry engineers, and researchers participate
- Solve difficult problems from social needs together
- Create only one or best technologies

Engineers — New technologies

Industry

- Collaborative industry-academia R&D and commercialization for competitive domains
- Build business models (including standards creation)

University-originating ventures

Sophisticated personnel

Jointly-developed technologies and IP

Trust- and cooperation-based matching

Introduce seeds

Needs Research costs

Creation and development

Support — **Government** — Support

Waseda Open Innovation Valley Project

➢ **Research Innovation Center to be completed in March 2020**
➢ **Industry Academia Collaboration One Stop Desk, Research Support and Strategy, TLO, Contract Support, Venture Start-up Support**

Waseda Main Campus

March 10, 2021 in Waseda Arena
Waseda Open Innovation Forum (WoI) 2021
(Matching among Leading Professors & Researchers, Industry, Ventures, Students)

New Research Innovation Center (Open: April 2020)

Supported by MEXT **Open Innovation Project**

Toyama Campus

Supported by METI

Green Computing Center for Industry Collaboration

Waseda Arena with roof garden: Collaboration in Sport Science