Intelligent RT Software Project

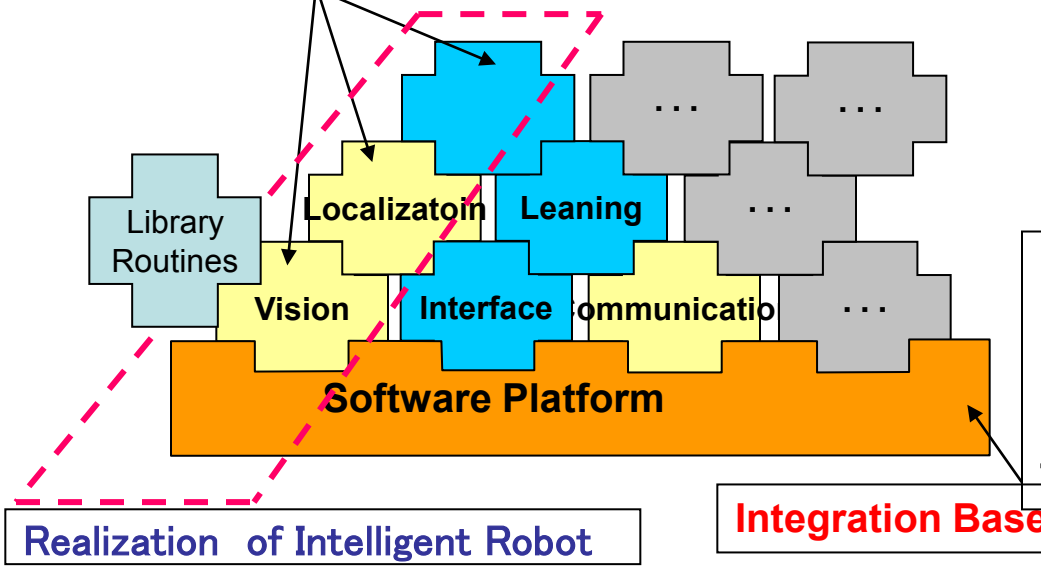
～Next Generation Robot Projects sponsored by NEDO: Ministry of Economy, Trade and Industry～

Problems to be solved

- The robot system tend to be developed from scratch.
- It takes time to reach high level robot performance.

Project Requirements

- Software platform is needed on which intelligent RT software modules can be integrated.
- Robust intelligent software modules are required to realize an intelligent robot.



Practical Robot

Robot + RT Services

+ Social mechanism

Intelligent RT software modules offer basis of realizing cost-effective robot with useful functions.

robotics/2012-12-03

Re-usability of software modules：Project Key

・Modules should have common interface	Set common interface by establishing sub-WG
・Modules should have integrity	Repeated integration evaluation by performing demonstration
・Modules should be exchangeable	・Accepted research group focused on module utilization ・Combined research groups to stimulate mutual utilization of modules ・Made full use of determined common interface
・Modules should be easy to use	・Started open source software development ・Put stress on writing manuals and documents
・Modules should be useful	・Evaluated developed modules by realizing ann integrated robot ・Wrote documents and manuals
・Modules should be complete to realize intelligent robot	・Evaluates the completeness of software modules by demonstration during international exhibition

Research Targets

4 Targets consisting of 8 Research Items

Ⅰ. Software Platform

- ①－1 Development of intelligent robot software platform
- ①－2 Improvement of reusability of software modules

Ⅱ. Intelligent software modules for manipulation

- ② Manipulation inteligence（Industrial robot）
- ③ Manipulation intelligence（Social・Life area）

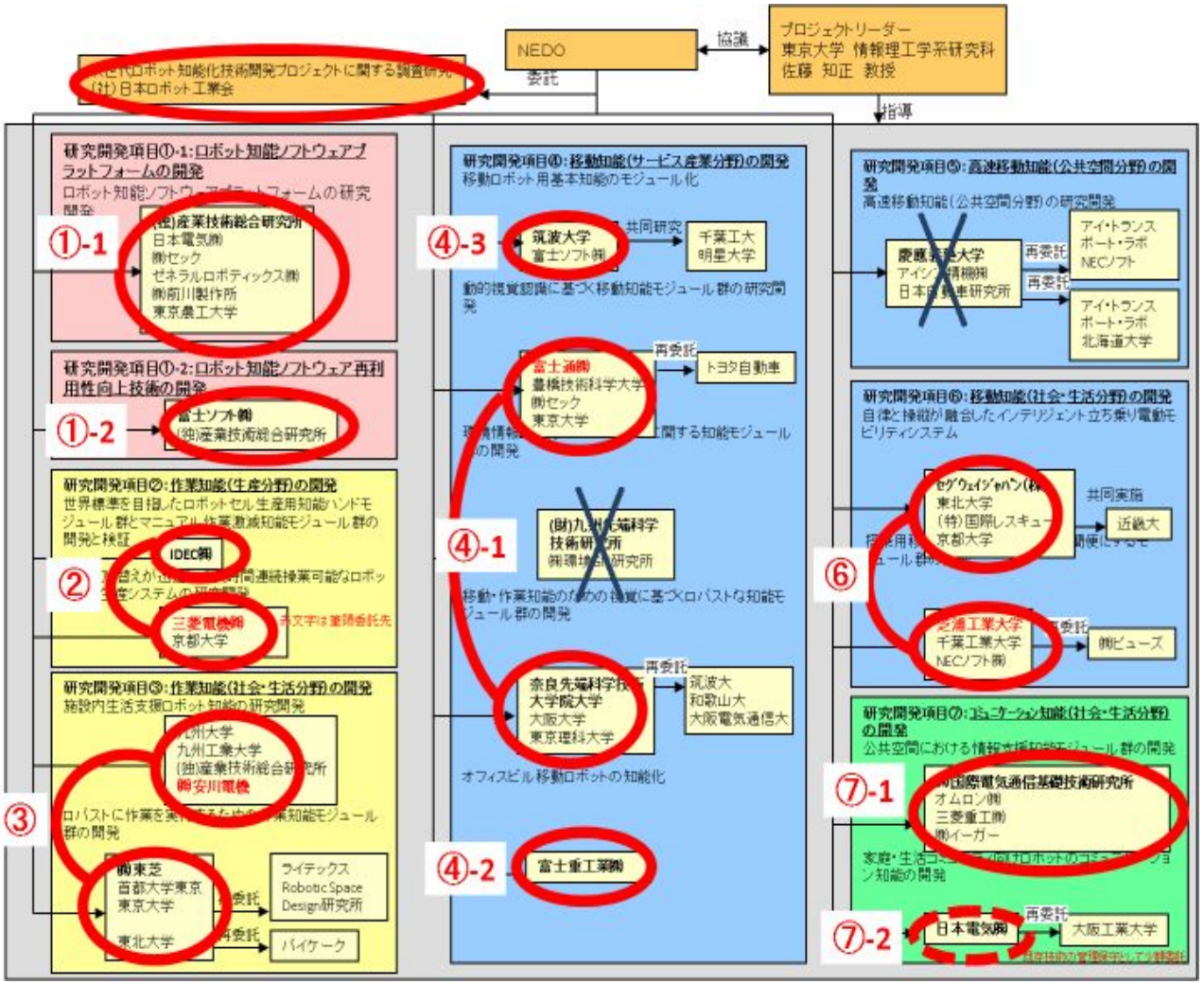
Ⅲ. Intelligent software modules for navigation

- ④ Navigation Intelligence（Service robot）
- ⑤ Rapid navigation intelligence（Public space）
- ⑥ Navigation Intelligence（Social ans Life area）

Ⅳ. Intelligent software for communication

- ⑦ Communication Intelligence（Social life area）

Project Formation
at the beginning and after midterm evaluation



再利用性の強化による実用化への対応

1. 他のコンソとのつながりが薄い(独立している)事業を終了した

2. 統合検証を行うため、開発内容が近いコンソを統合した

3. 一部モジュールをオープンソースで提供することとした

Research Coverage and Research Institutions

Basis

①Robot Software Platform (AIST,NEC,SEC,Mayekawa,GR,TUAT)

①-2 Intelligent RT Softw are Modules Verification (AIST,Fujisoft)

Manipulation

②Manipulation Intelligence（Industrial Field）(Mitsubishi Electric, Kyoto Univ.,**IDEC**)

③Manipulation Intelligence（Social･Life related Field）(Toshiba, Tokyo Metropolitan Univ., Univ.Tokyo,Tohoku Univ.,Rightechs,Robotics Space Design, PieCake, KYUTECH, Kyushu Univ., AIST,Yaskawa)

Mobility

④Mobility Intelligence（Service Industrial Field）(Fujitsu,TUT,SEC,Univ.Tokyo,Toyota,Univ.Tsukuba,Fujisoft,Chiba I.T.,Meisei Univ.,NAIST,Tokyo Univ. Science,Osaka Univ.,Wakayama Univ.,OECU, Fuji Heavy, ISIT, ENGIS)

⑤High-speed Mobility Intelligence（Public Facility Field）(Keio Univ., JARI、AISIN, itransport,NECsoft,Hokkaido Univ.)

⑥Mobility Intelligence（Social･Life related Field）(Segway Japan, Kyoto Univ.,IRSI,Tohoku Univ.,Kinki Univ.,Shibaura I.T.,Chiba I.T.,NEC Soft, PUES)

Communication

⑦Communication Intelligence（Social･Life related Field）(NEC, Osaka I.T. , ATR,Omron, MHI, Eager)

Project Management

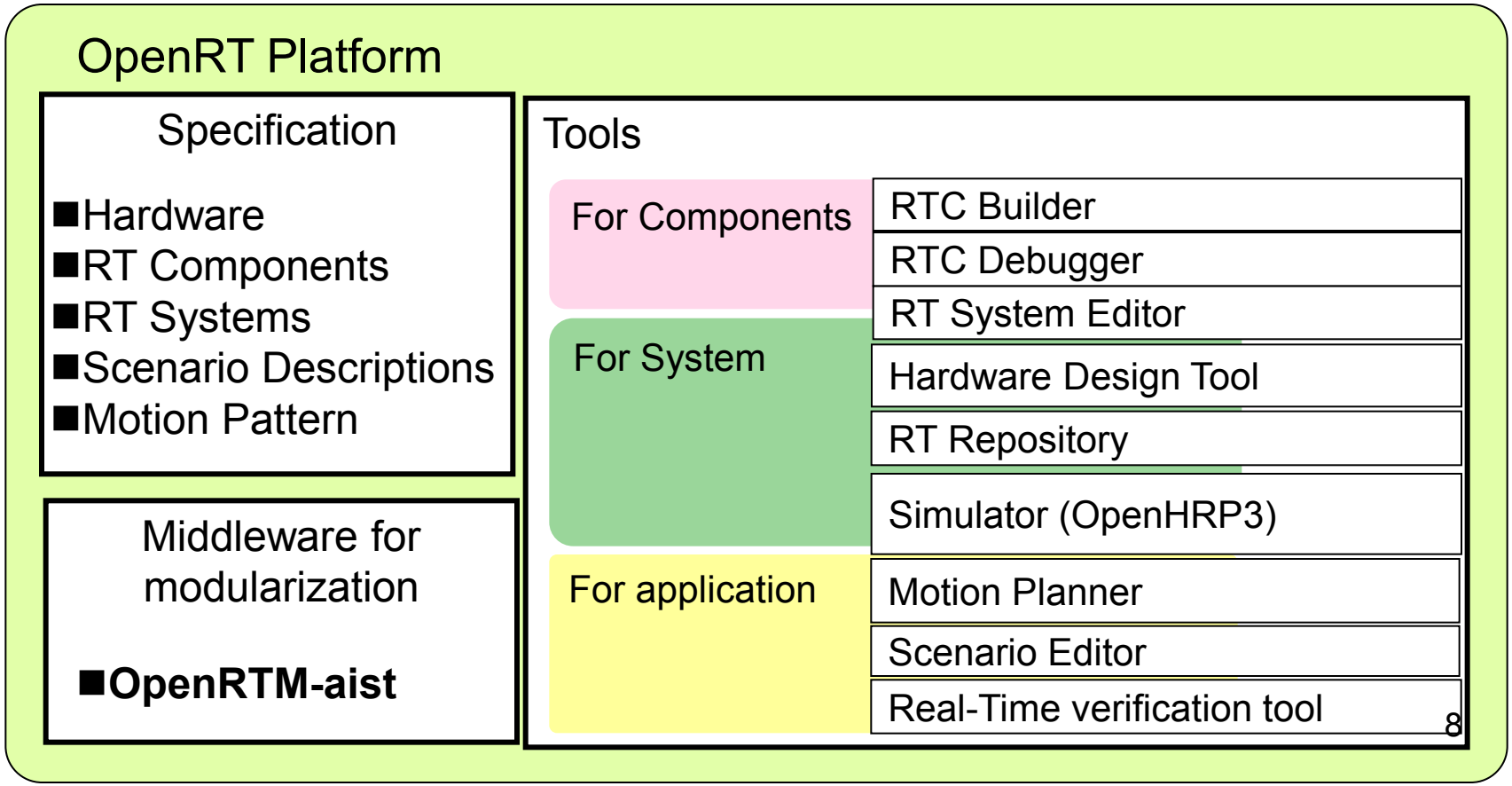
2007	■Rapid start of project Add new research team responsible for only module utilization
2008	■ Start sub-working group of manipulation, navigation and communication to realize common interface amang modules Execution of demonstration in early project stage
2009	■Started re-usable center to verify all modules ■Project steering at every Thursday from Akihabara Midterm-evaluation ■Started Working Team and rearrangement of research teams
2010	■Open source development by additional funding ■Development of dual eye&arm robot software
2011	■Promoted final evaluation of all developed modules ■RTM-Ros interoperability project ■Development of RTM safety ■Efforts to make the module in practice

Project Basic Output

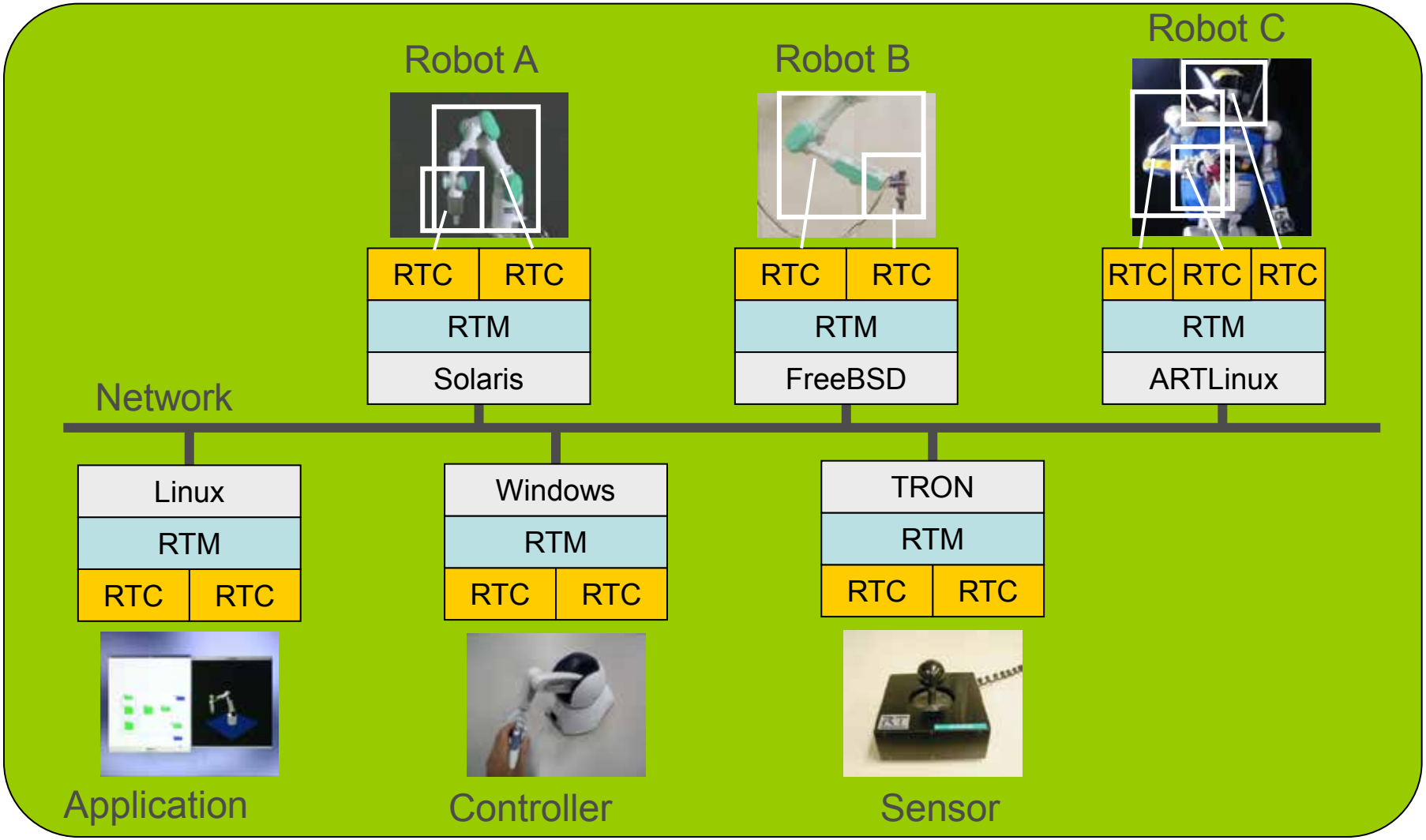
Software Platform

～Overview of Intelligent RT Software Platform～

- Integrated development set
  for developing RT components, RT systems
  and application scenarios

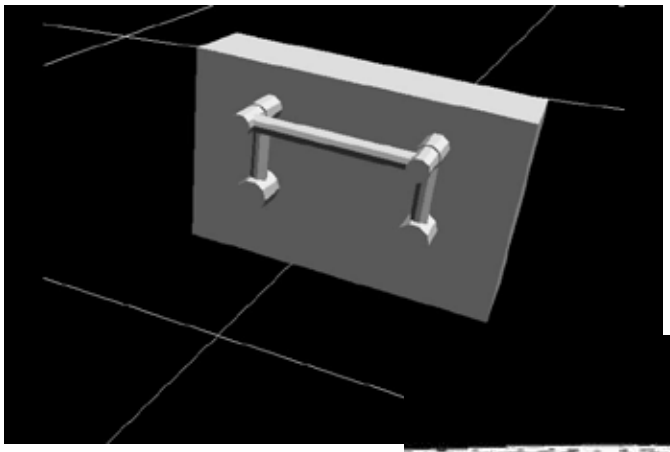


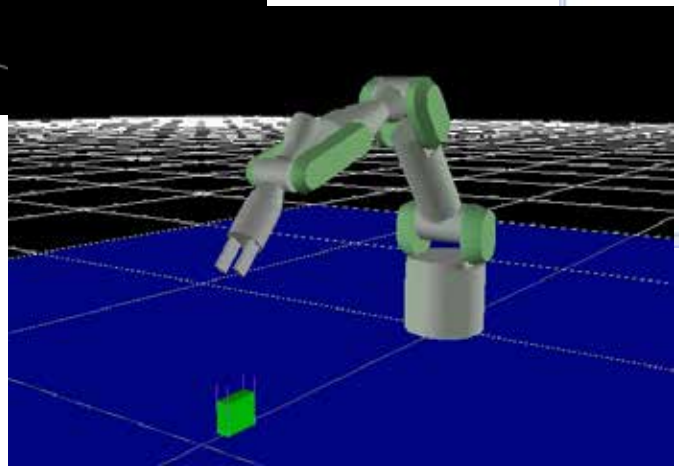
Robot System based on OpenRTM-aist-1.1

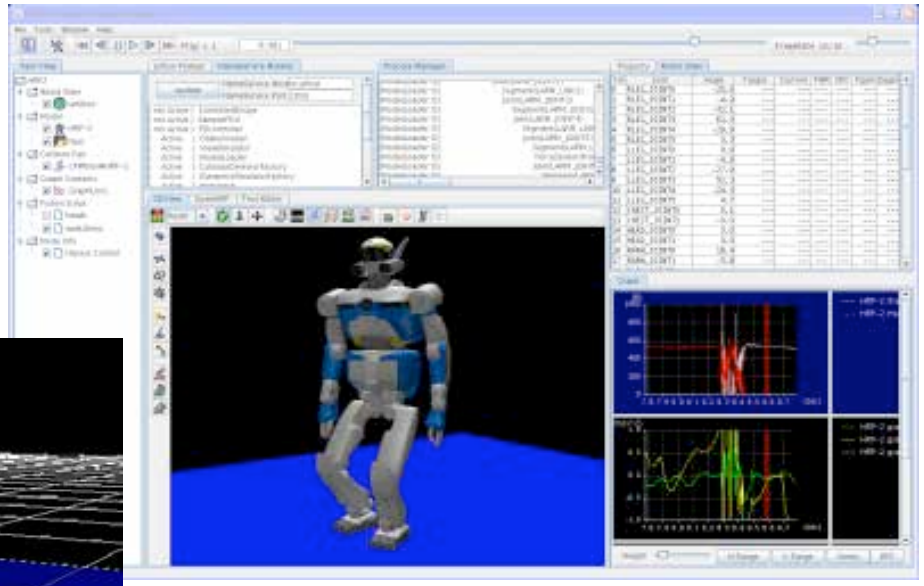


Dynamics Simulator: OpenHRP3

- Featherstone‘s O(N)　algorithm
- Contact force simulation using LCP solver
- Sensor simulation :
  accelerometer, gyro, force/torque sensor,
  camera, range sensor

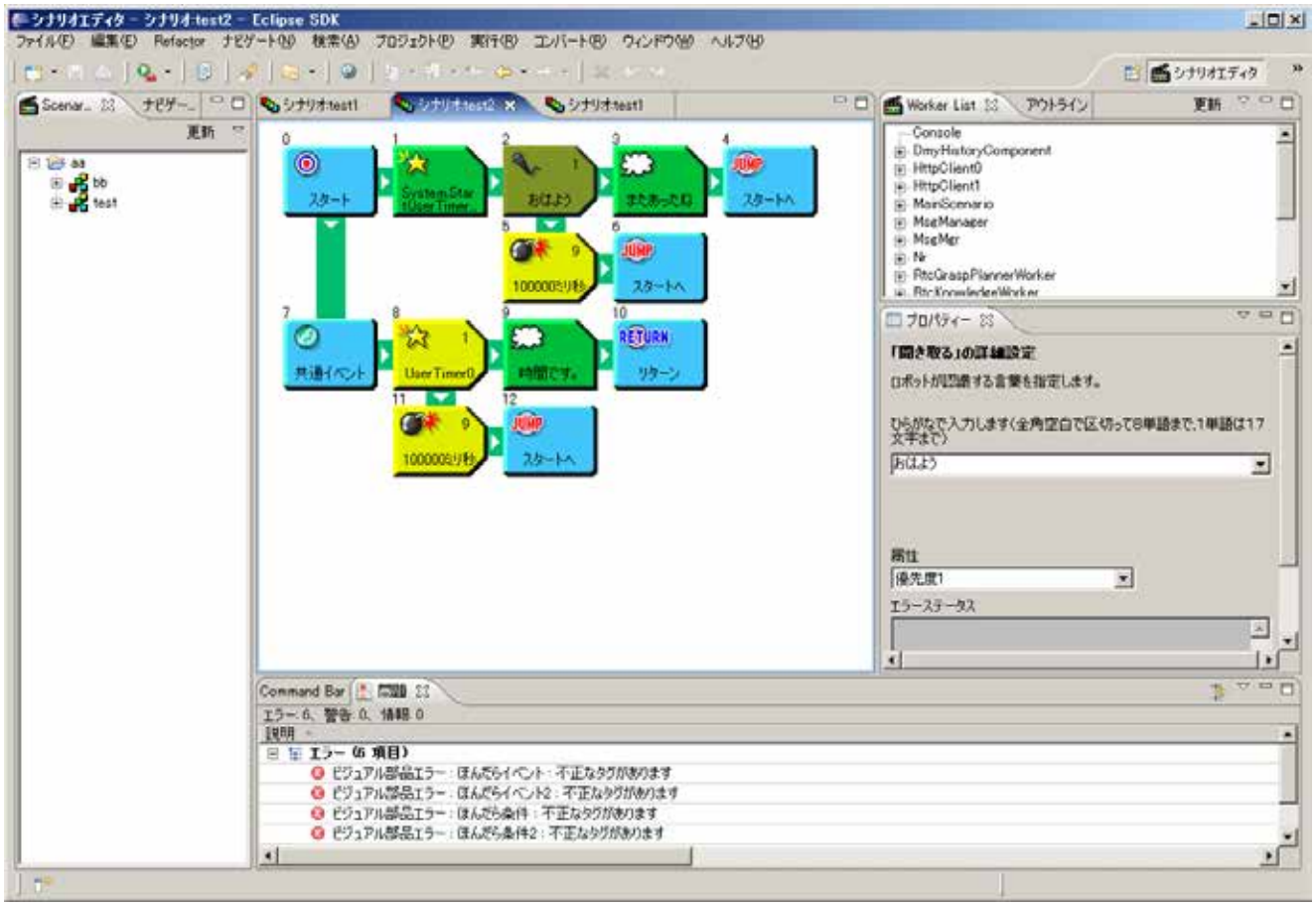






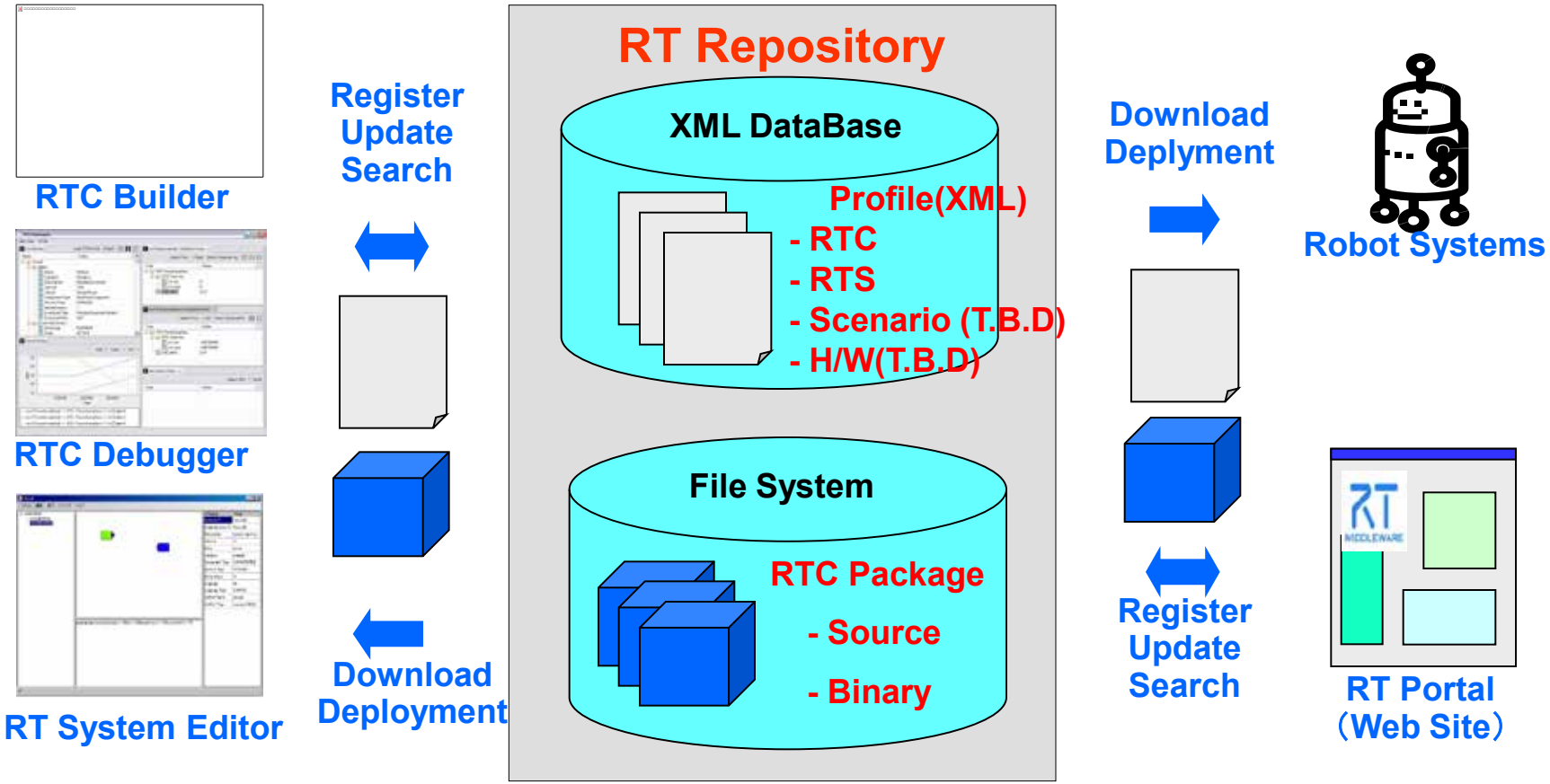
Scenario Editor

- Create and edit a sequence of motion patterns by using a script language or GUI
- Control event flow among RT Components



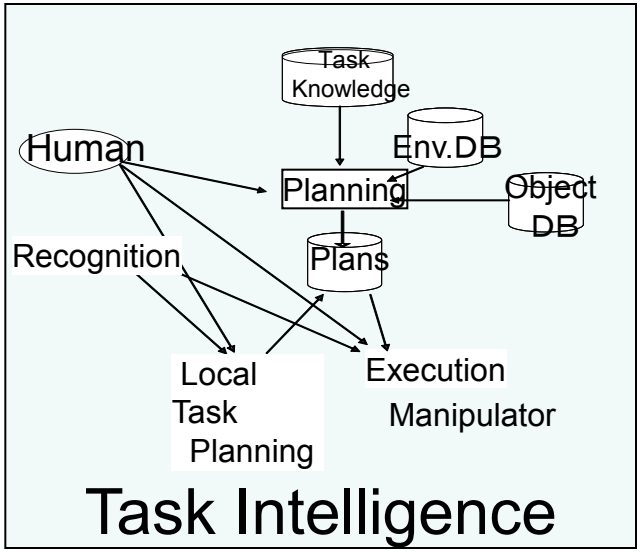
RT Repository

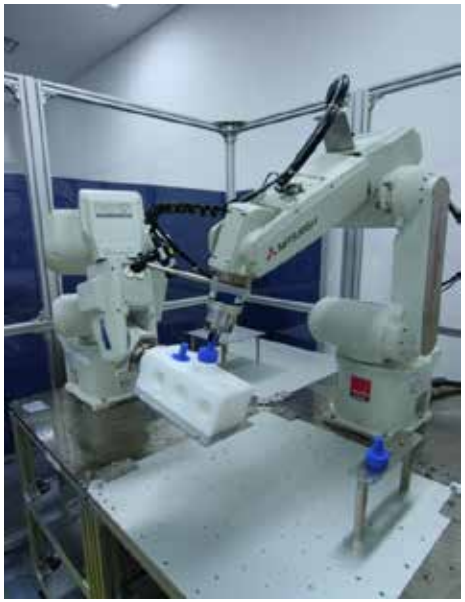
- Public/personal database for RTC/RTS etc.



Intelligent RT Software Modules

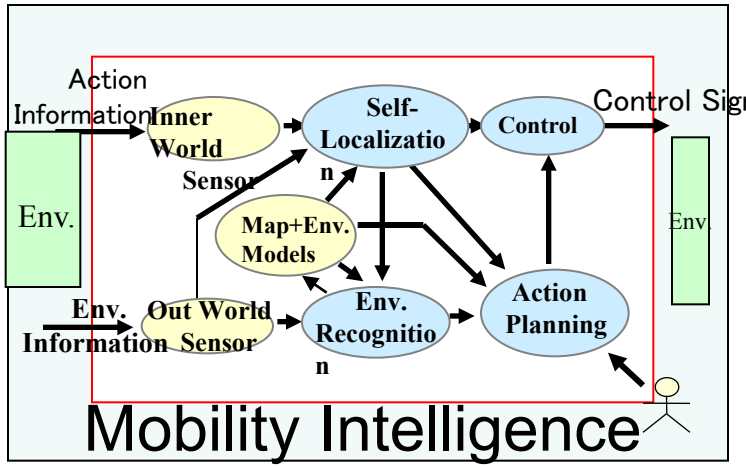
Manipulation





Intelligent RT Software Modules

Navigation



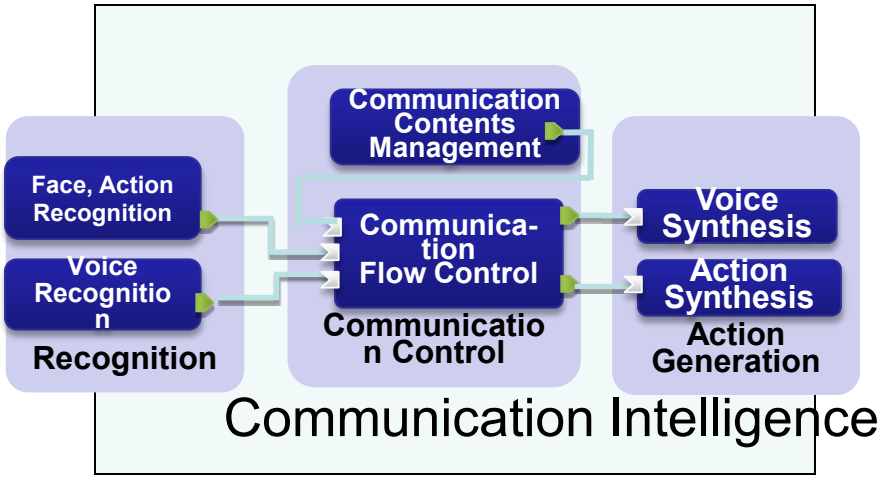
Prototype 1

Prototype 1
With ABS cover

Prototype 1
With Metal cover

Intelligent RT Software Modules

Communication



Number of developed Modules

Number of Developed Modules（ Target：340）					
2007	2008	2009	2010	2011	Total
48	136	120	16	42	362

Intellectual Properties

	Patent（出願）	Research Presentation（Papers、Conference）		PR	
		International	Domestic	Mass Media	Exibition
2007～2009	50 (0)	55	336	119	57
2011	13 (7)	53	172	44	5
2012	5 (0)	51	99	60	11
Total	6 8(7)	159	582	223	73
		766			

Towards Practical Utilization of RT modules ～Steps and Efforts～

1st Step

- Accumulation of practical RT modules

2nd Step

- To offer software platform and RT modules

3rd step

- Contribution to National Requirements

Towards Practical RT Module Application

1st Step

- **Accumulation of practical RT modules**

1) Open source development of intelligent RT components for palletizing tasks by dual-eye&arm robot

2) Open source development of intelligent RT components for assort tasks by dual-eye&arm robot

1）Open Source Development of Intelligent RT Components for Palletizing tasks by Dual-eye&arm Robot

作業例：ピッキング、パレタイジング、搬送など

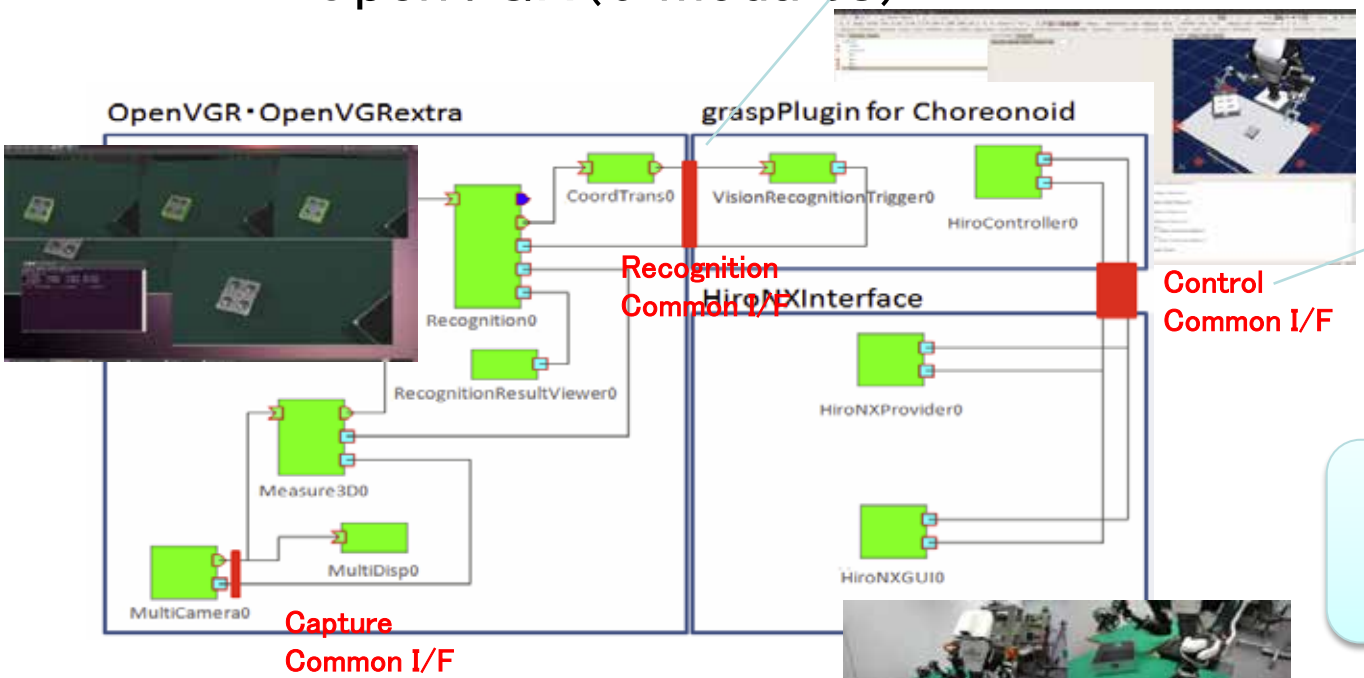
System

Sense

Plan

OpenVGR(6 modules)

graspPlugin for Choreonoid (2 modules)



Act

HiroNXInterface (2 modules)

User Can Select the best Module

Scheduler

Sense

IEEE1394b Stereo camera

Single USB camera

Rangefinder SwissRanger

Kinect

Recognition Common IF

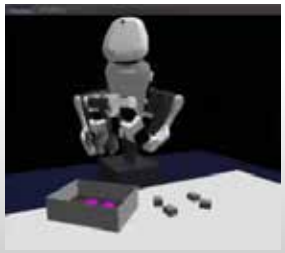
Plan

Grasp Plan

Motion Control

Motion Plan

Cooperative Control



Dual-arm robot control Common IF

Act

AIST

Tokyo

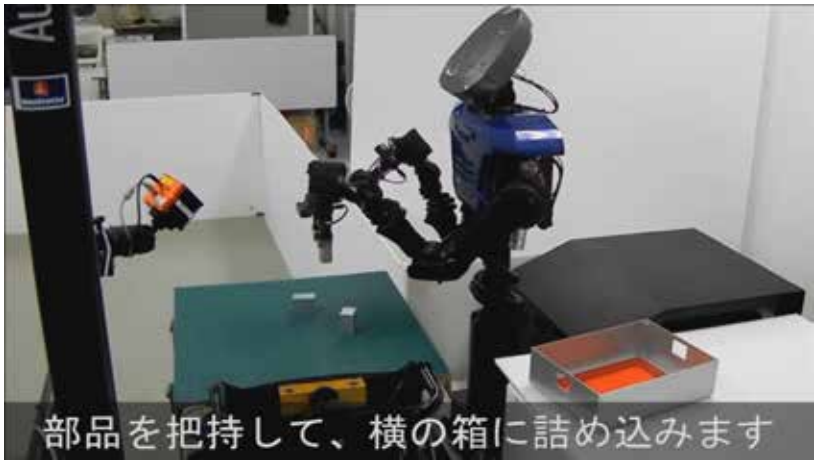
Toyohasi

Tohoku

Video of each system

AIST 頭部ステレオカメラを用いた双腕ロボットによるマニピュレーション作業

東京大学 THE UNIVERSITY OF TOKYO 手先カメラを用いた双腕ロボットによるマニピュレーション作業システム



TOYOHASHI UNIVERSITY OF TECHNOLOGY 双腕ロボットとAGVの連携システム

東北大学 双腕ロボットによる双腕協調マニピュレーション作業

2)Open Source Development of Intelligent RT Components for Assort tasks by Dual-eye&arm Robot

Assort tasks for service robot

NAIST

Osaka University

Tokyo University of Science

Tsukuba University

AIST

Over-the-counter sales robot system

This project presents a dual-arm service robot system reusing open source RT components. The service robot system has four functions which are user detection, user interface, ordered object(Japanese confections) recognition and ordered object manipulation. Each function is developed by several groups as an open source RT module.

Scenario

Python sample scenario（IREX2011）

Each module controlled by the scenario

User detection

Camera image based modules
LRF data based modules

Object recognition

Template matching based modules
SIFT based modules
Background subtraction based modules
Bar code based modules

User interface

Web browser based modules
Voice input based modules

Robot Control

Dual-arm control modules

Target: Japanese confections

Turuyahatiman

Turuyahatiman

Tsuruya Yoshinobu

Fugetsudo

Turuyahatiman

GODIVA

Tsuruya Yoshinobu

MARKT

Morozoff

Taneya

Taneya

ANTÉNOR

PIERRE HERMÉ

Osaka Univ.

Cracker

Taneya

MARKT

MARKT

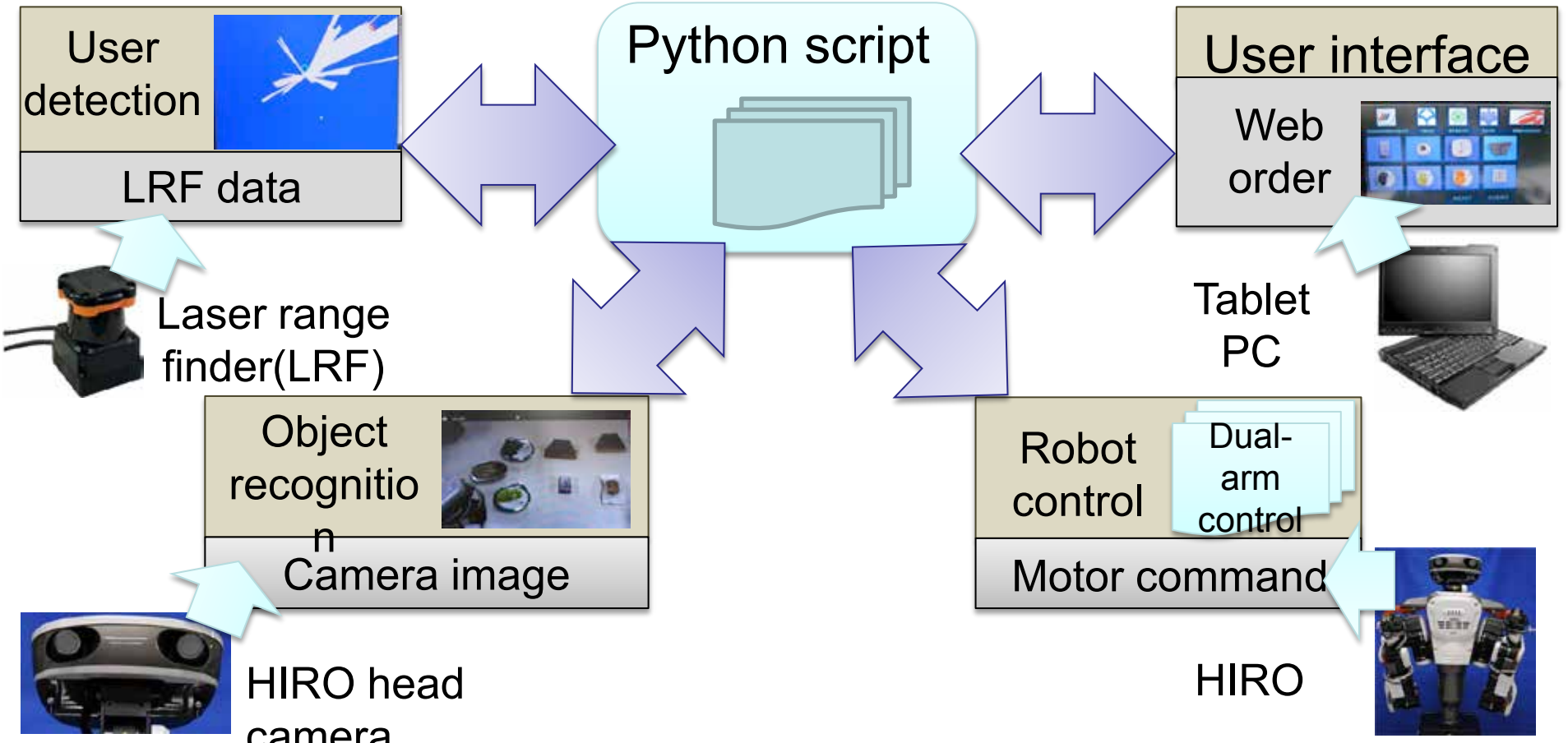
BOUL'MICH

Challenges

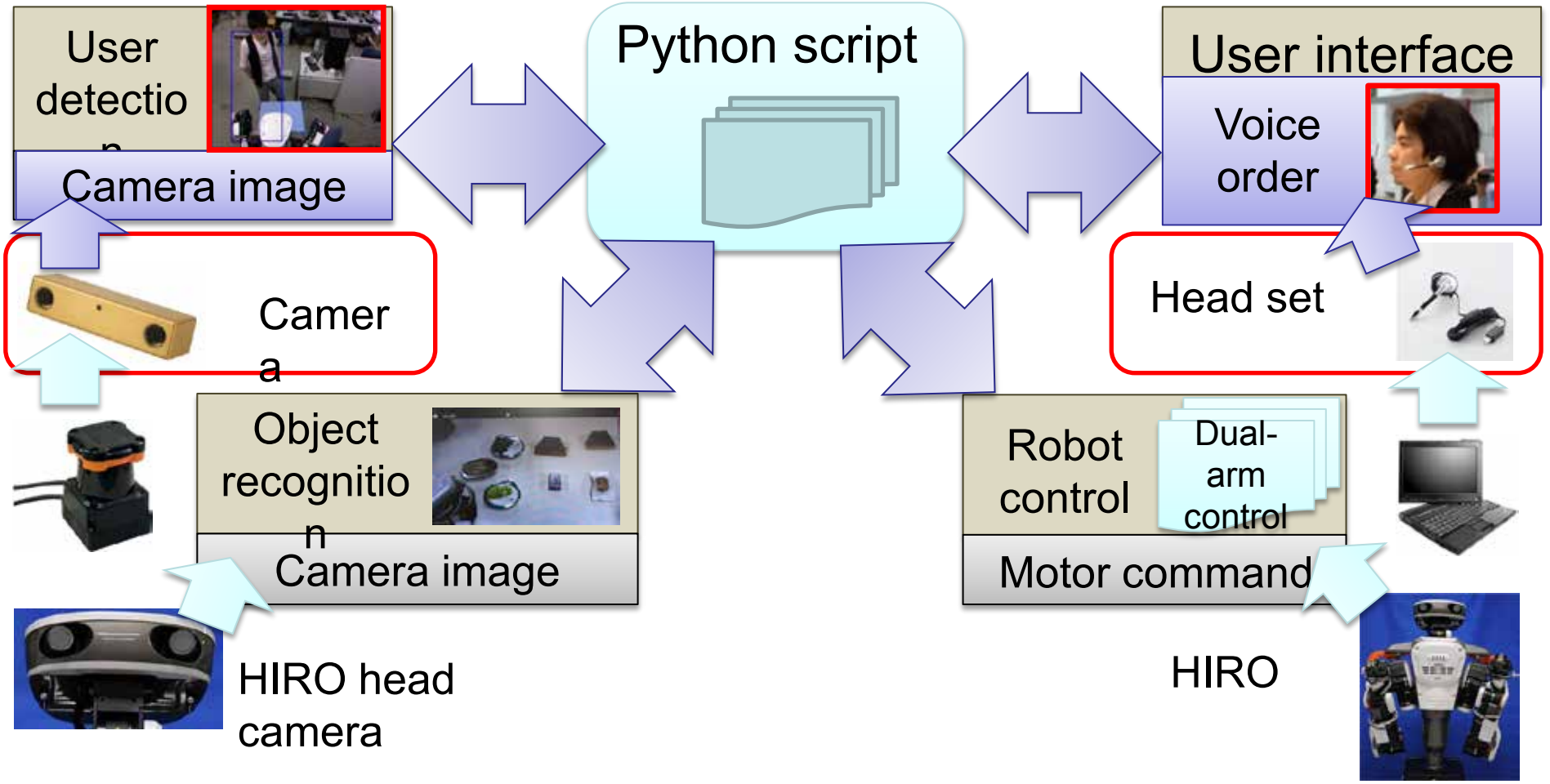
- Easy system integration
- Standardized interface of RT modules
- Easy replace of RT modules
- Using open source RT modules

Demonstration at IREX 2011

Setup of RT modules



Setup of RT modules: Changed hardware



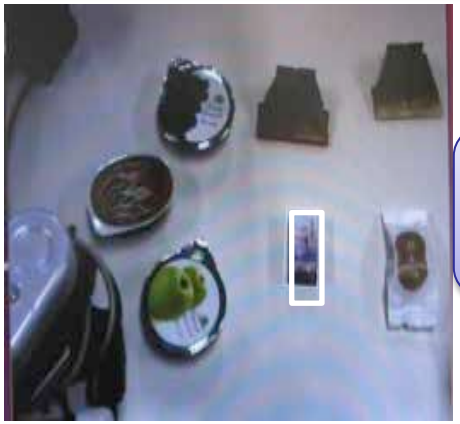
System updating

Easy to replace to a new module which has new algorism

Object recognition

Template matching position/pose estimation

Appearance based position/pose estimation



Template matching

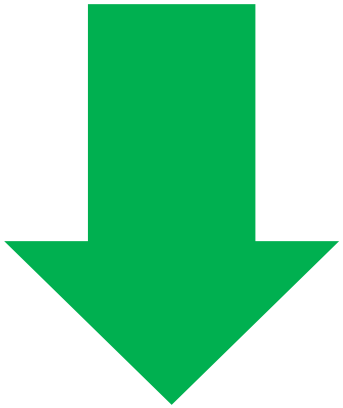
SIFT matching

Assort task by dual eye&arm robot（Tsukuba Univ.）

Towards Practical RT　Module Application

2nd Step

・To offer software platform and RT modules



1）Robossa

2)Inter-operability between RTM and ROS

1）Intelligent Robot Software Suite

— ROBOSSA —

Intelligent Systems Institute,
AIST

— ROBOSSA —

(Open Source RT Components)

- Organize in three categories:

  Manipulation, Navigation, Communication

  Accumulation of basic software modules for intelligent robots

- Open source intelligent robot software modules

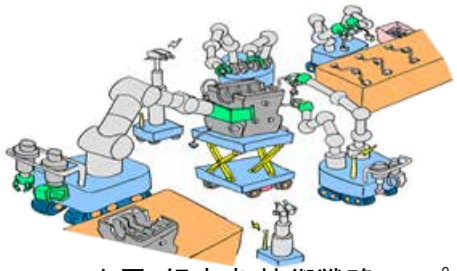
  Collection of enabling modules to select and combine freely

- Commercial robots are supported.

  Collection of modules easy to use on available reliable robot

Intelligent Robot Software Suite

— ROBOSSA —



出展：経産省 技術戦略マップ 2010

RT MIDDLEWARE

OpenRTM PLATFORM

OpenRTC-aist

＋ New function, technique

Industrial Robot Platform

New Service

New Hardware

Research Platform

New Sensors

New Tech.

Educational Robot Platform

Intelligent Manupulation

＋

Manipulation

ステレオ視
作業計画
把持計画
物体認識

Mobility

自己位置推定
経路計画
軌跡追従
地図作成
障害物回避

＋

Mobile Robot

Communication

話す
対話制御
聴く
音声認識

＋

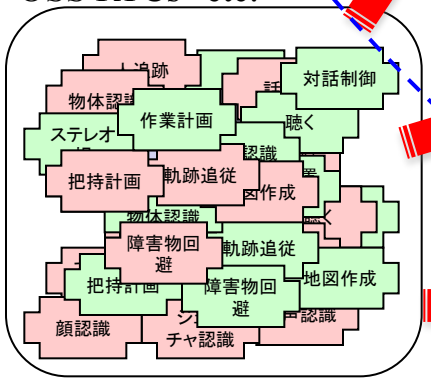
Communication Robot

NEDO-RTCs
OSS RTCs etc.

select

select

select



Intelligent Software Module ＋ Commercial Robot

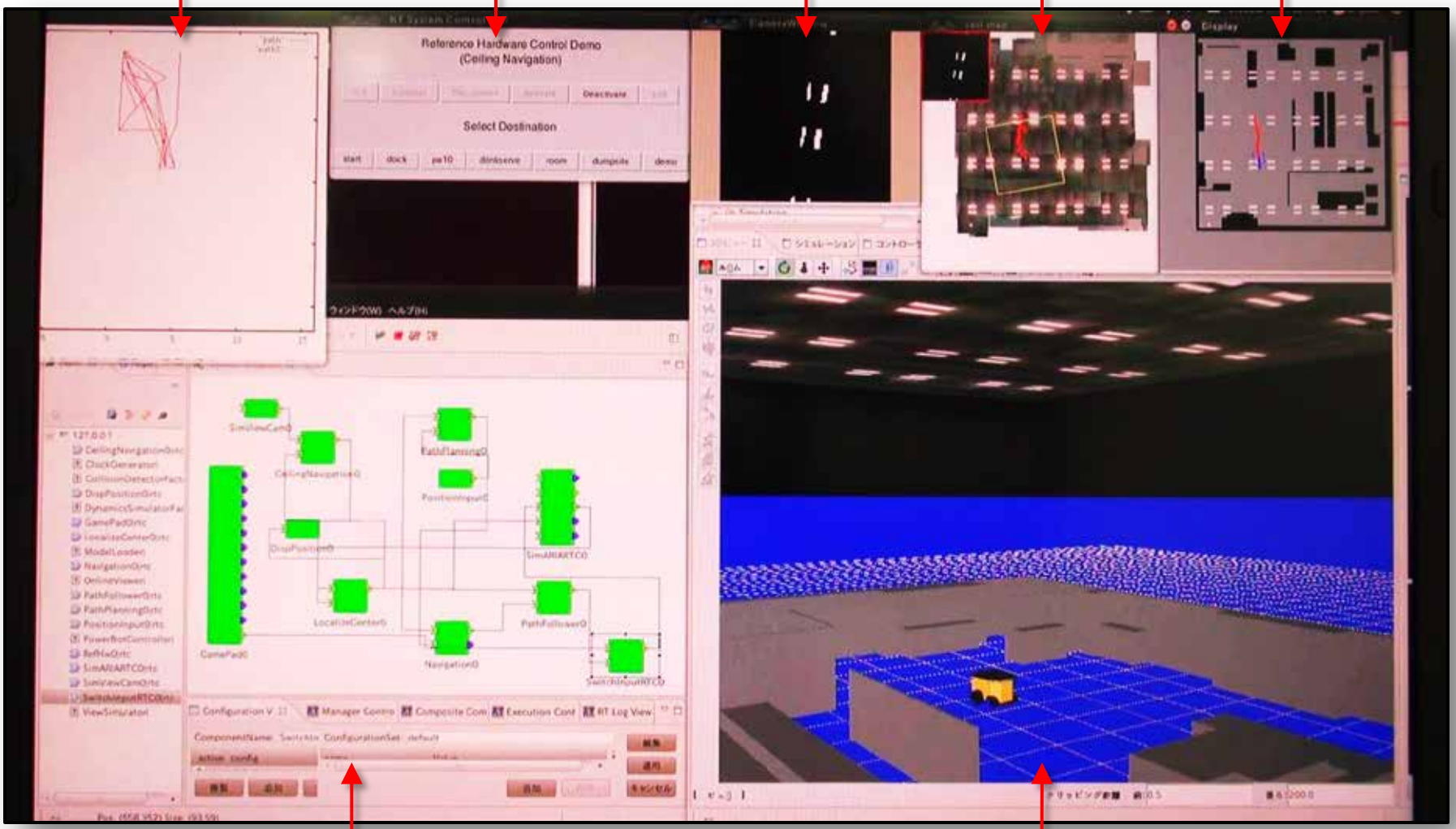
RT-Components for Mobile Robots (OpenNavigation)

- Base on the common interface of mobility intelligence
- Mobility functions for wheeled robot to follow the pathway
- Modules developed in the intelligent robot software project

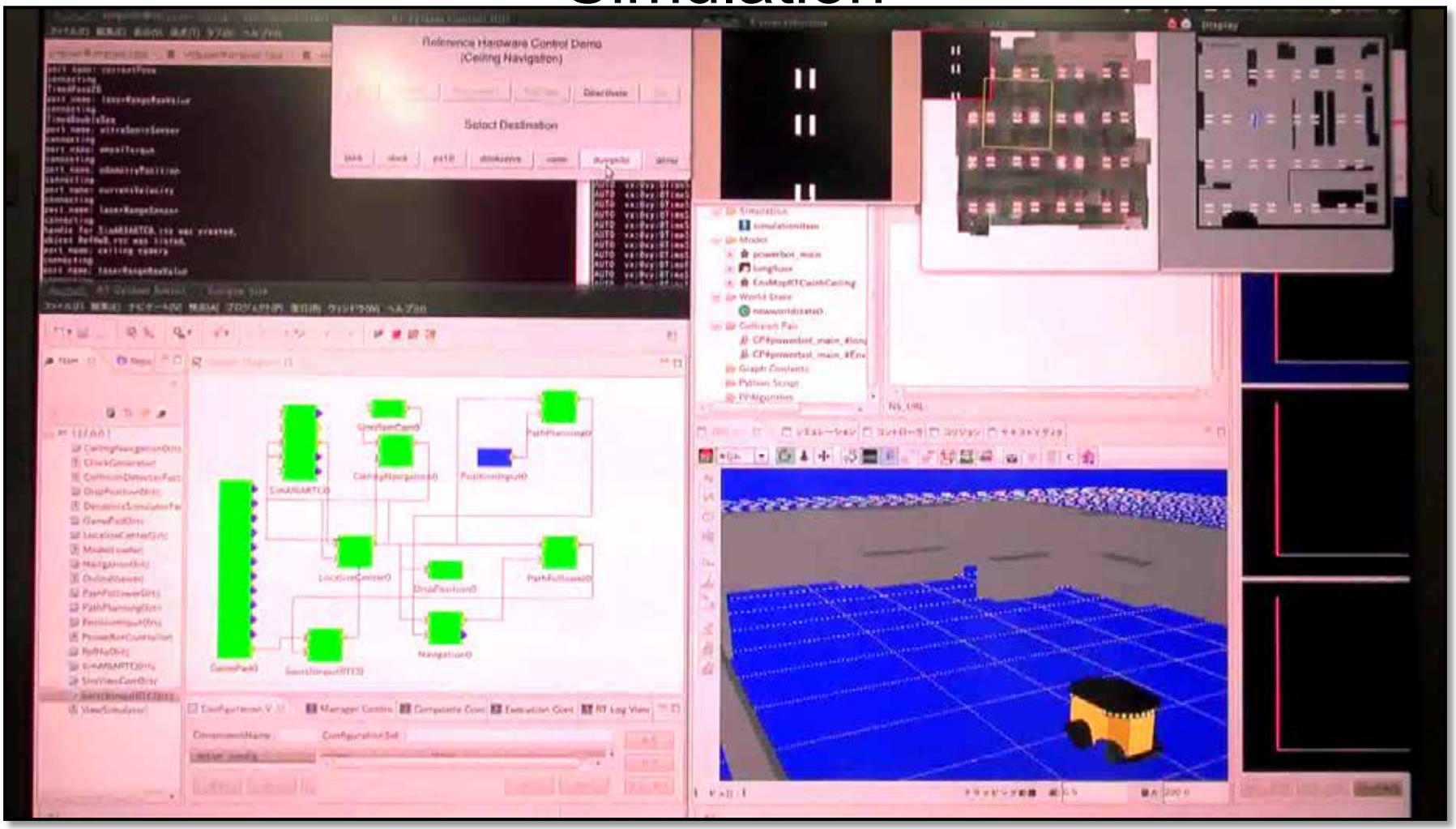
  - Sensing（2 modules）
  - Self-localization（4 modules）
  - Mobility control（3 modules）
  - Path planning and Path tracking（4 modules）
  - User-Interface（2 modules）




Ceiling Navigation



Simulation


Reference Hardware Control Demo
(Ceiling Navigation)
Select Destination

2）OpenRTM-ROS interopelablity

University of Tokyo

OpenRTM and ROS: Comparison Overview

- OpenRTM is designed on RTM standards and focus on a quality guaranteed component development, specially for the enterprise users.
- ROS is designed for research community and focus on providing development environment.

	OpenRTM	ROS
Sponsers	MITI, MEXT, NEDO	WillowGarage
License	Open / Closed	Open License (BSD)
PI	AIST	Open Source Robotics Foundation
Design Principle	Component Strict framework for re-usability	Library Loose framework for development speed
Quality Control	OMG standard Reusability Center	None (voluntary based control)

OpenRTM and ROS: locations and number of modules

- ROS
  - 114 repositories (including 14 companies = 8%)
  - 150 software modules (number of ROS stacks, number of package is 3000)
  - http://www.ros.org/wiki/Metrics
- OpenRTM
  - 45 repositories (include 15 companies = 33 %)
  - 332 software modules

OpenRTM is widely used in enterprise users

http://maps.google.com/maps/ms?ie=UTF&msa=0&msid=209668390659853657363.00049c608b78bc7779683

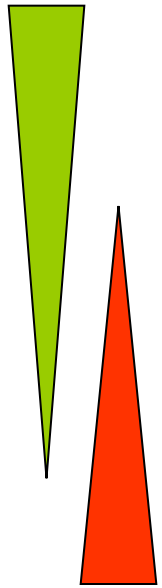
http://maps.google.com/maps/ms?ie=UTF&msa=0&msid=202046448223103795061.0004af11ddd066defcdfb

OpenRMT and ROS integration

What is ROS exactly?

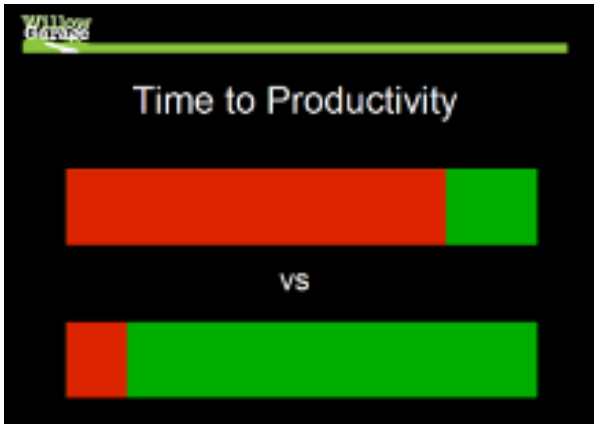
ROS = plumbing + tools + capabilities + ecosystem
B. Gerkey, Dec 06 ’11. answers.ros.org

- Application
- Modules
- Library
- Simulator
- Communication
- Device Drivers
- Tools



Research
Target of OpenRTM project

Tools
ROS provides extensive set in this layer



Red indicates time to build tools,and greer shows the research. Current PhD student spend most of their time to build tools. ROS is designed to provide efficient tools for researchers to concentrate on the “research”（Steve Cousins speaking at Robo Development：http://www.willowgarage.com/blog/2008/11/17/steve-cousins-speaking-robo-development-tuesday)

→ Builing OpenRTM-ROS environment on ROS-tools

- Connecting OpenRTM and modles developed in all over the word.
- Efficient development and maintenance

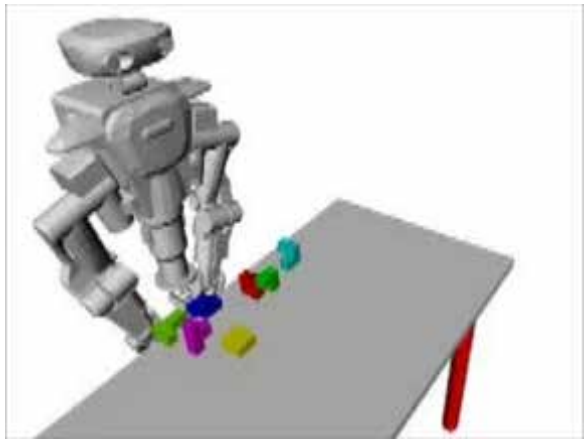
RTM-ROS Interoperability Project

(A) Interoperability platform hardware

1. OpenRTM Mobile base
   + ROS Navigation
   - Support common interface designed in navigation SW group
2. OpenRTM Mbile Base
   + ROS Navigatoin
   + OpenRTM manipulator
   + OpenRAVE Planning
   - Common interface is designed in manipulation group
   - Using joint angle interface of SequencePlayer

Mobaile robot beego

Yasukawa's mobile unit FMK

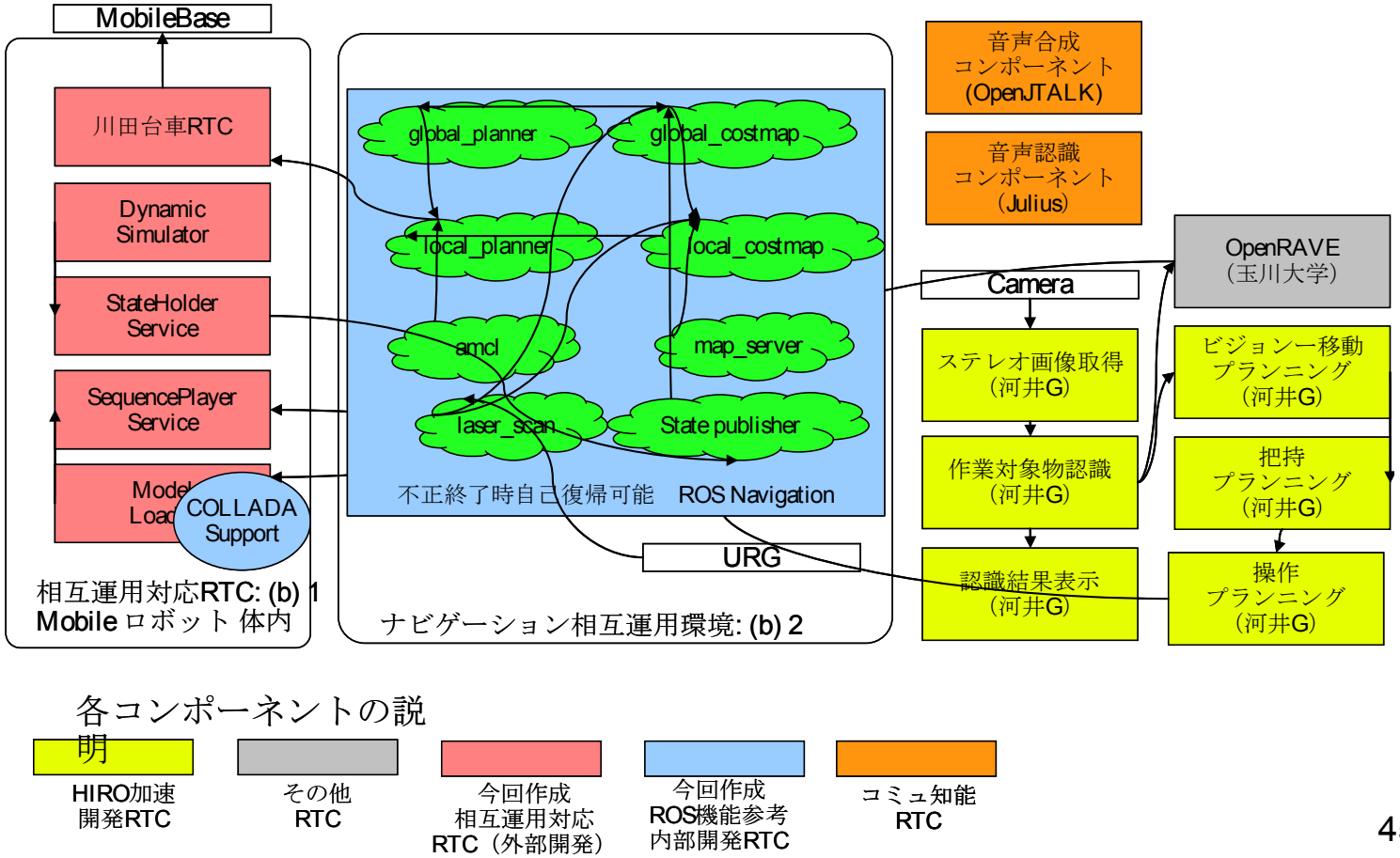


3D block manipulation using OpenRAVE

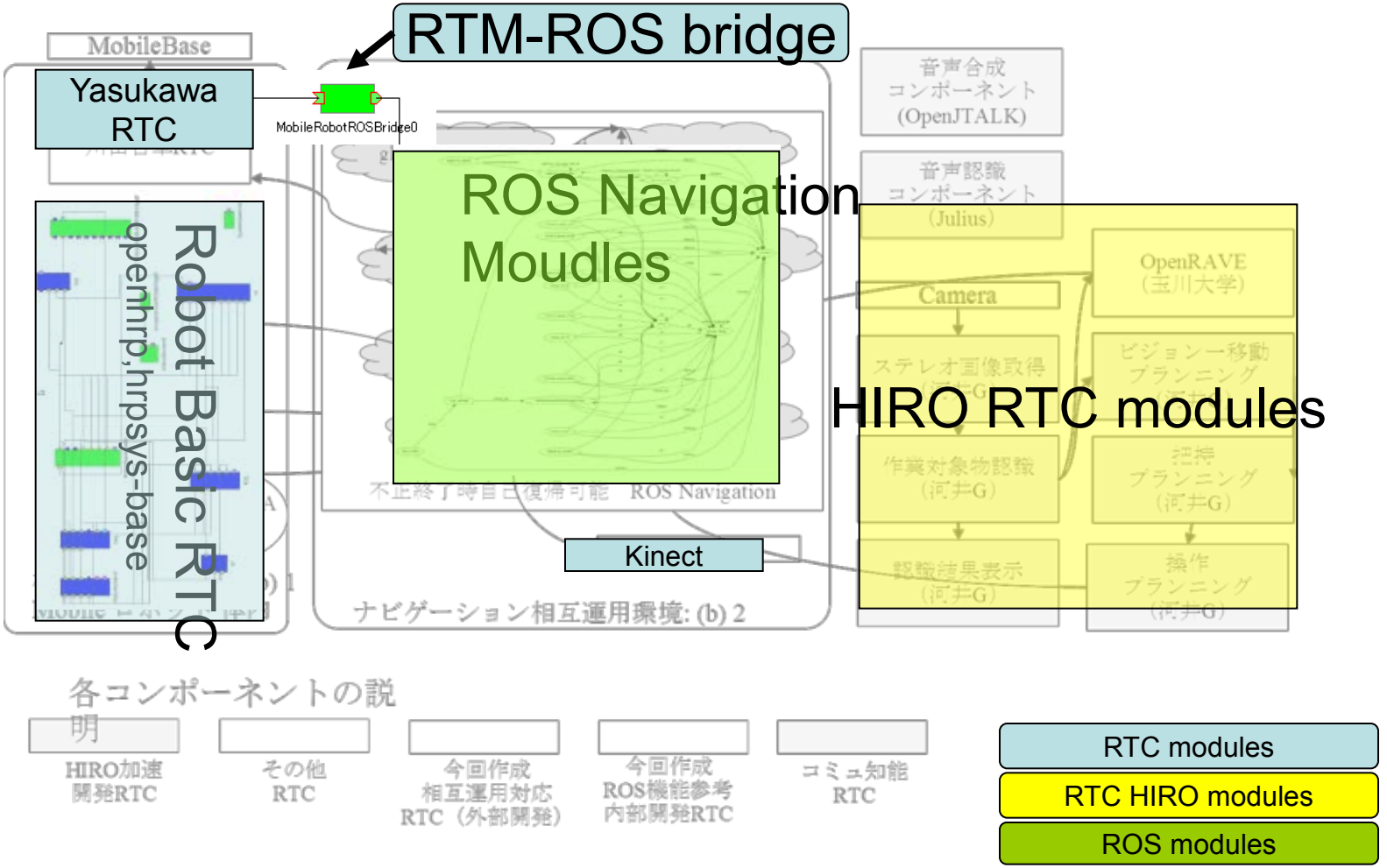
Mobile manipulation robot

RTM-ROS Interoperability Project

(B) Interoperability platform software design



(B) Interoperability platform software design

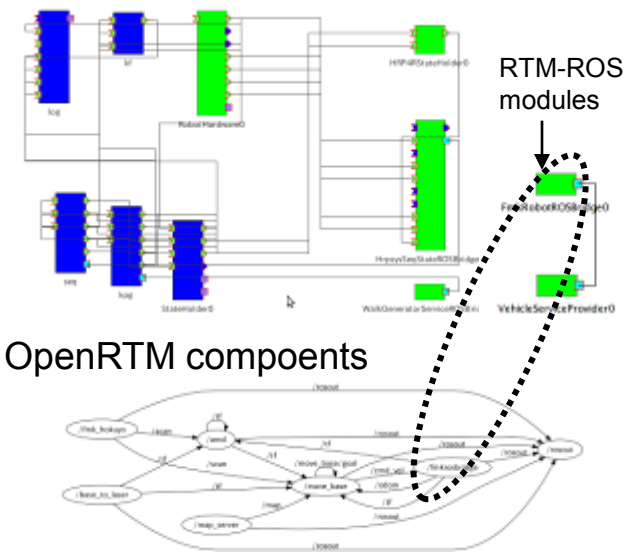


Experiments in Interoperability platform

ROS Navigation module on OpenRTM mobile robot base

Mobile Manipulation robot using OpenRTM Controller and ROS Interface

Mobile Manipulation Robot



ROS modules

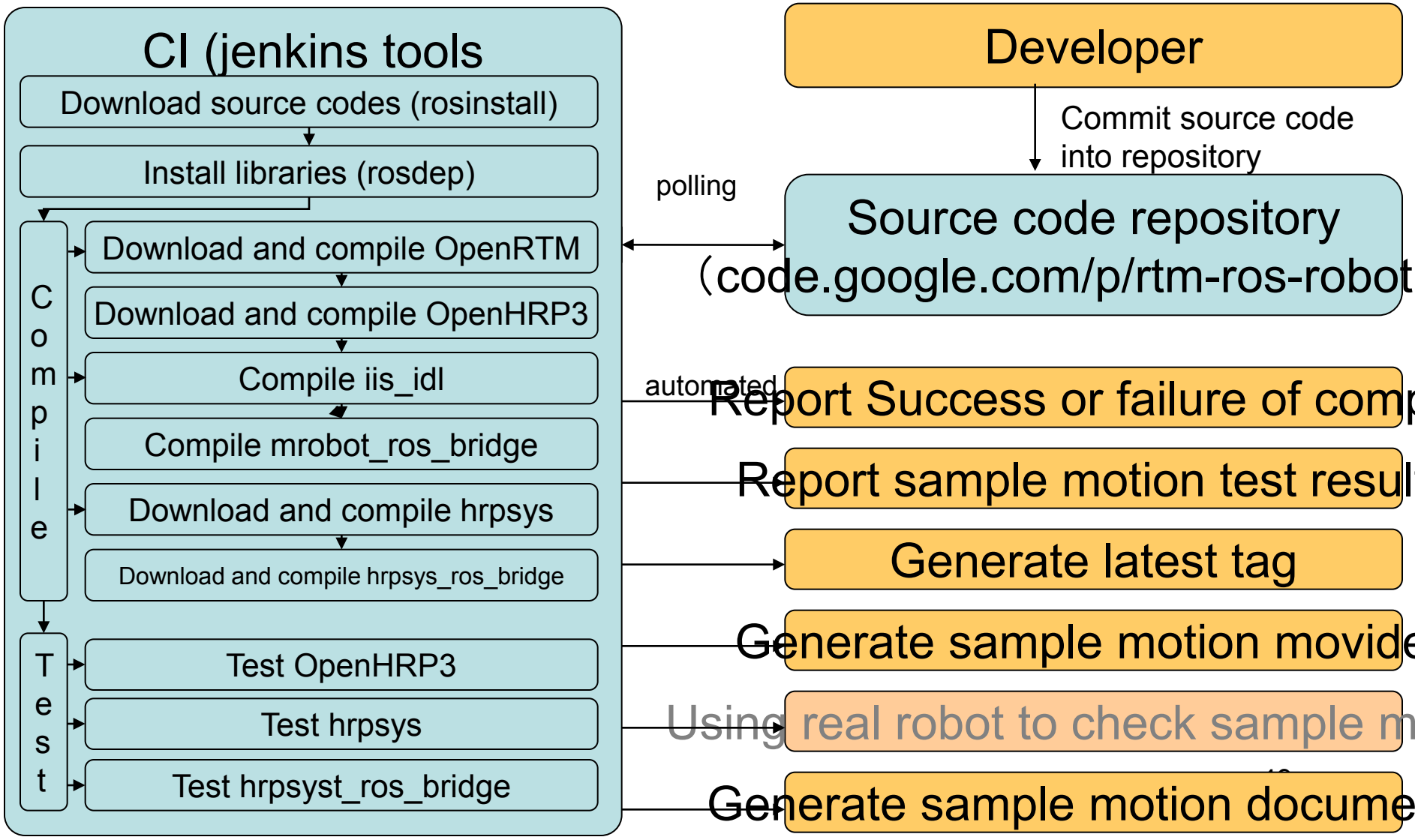
carry tray task experiment

RTM-ROS Interoperability Project

(C) Continues development of Intelligent RT Component

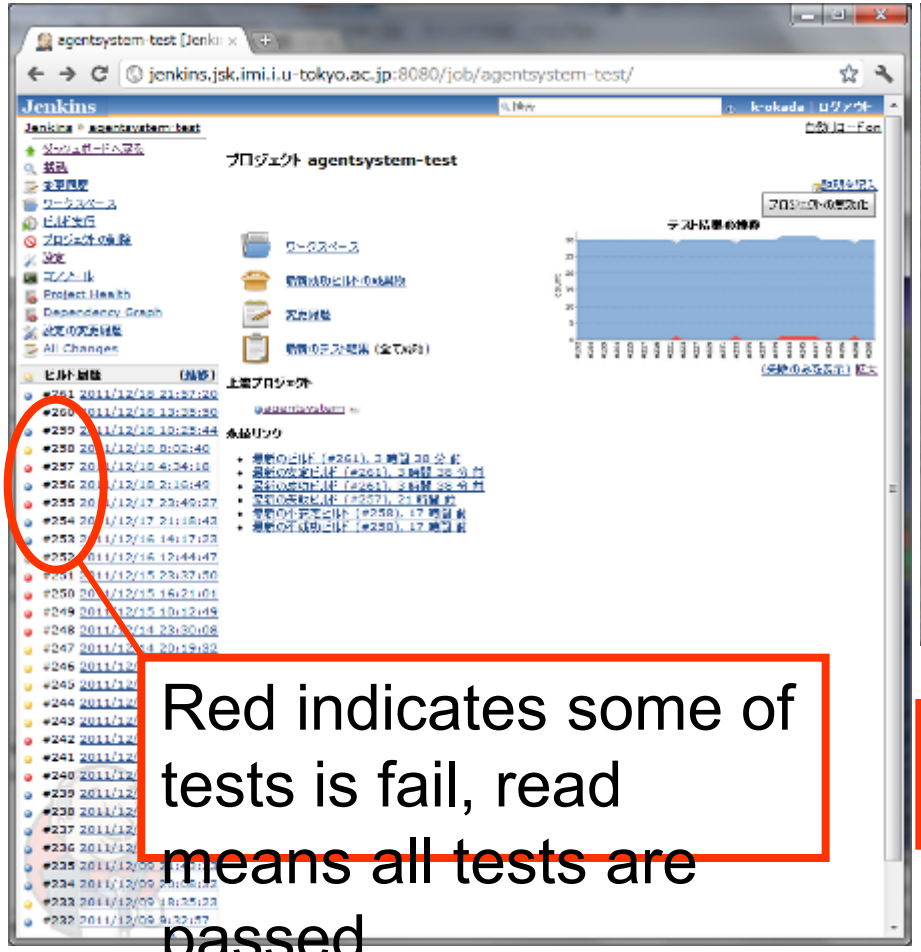
- Need framework that enable us to keep interoperability between OpenRTM and ROS even after the projects terminated
- Each software will continuously be improved respectably, interoperability tools need to adapt to such progresses
  - Automatic testing of intelligent components
  - Automatic tools to generate RTC component from ROS nodes

(X2) Automatic testing and documentation of RT components

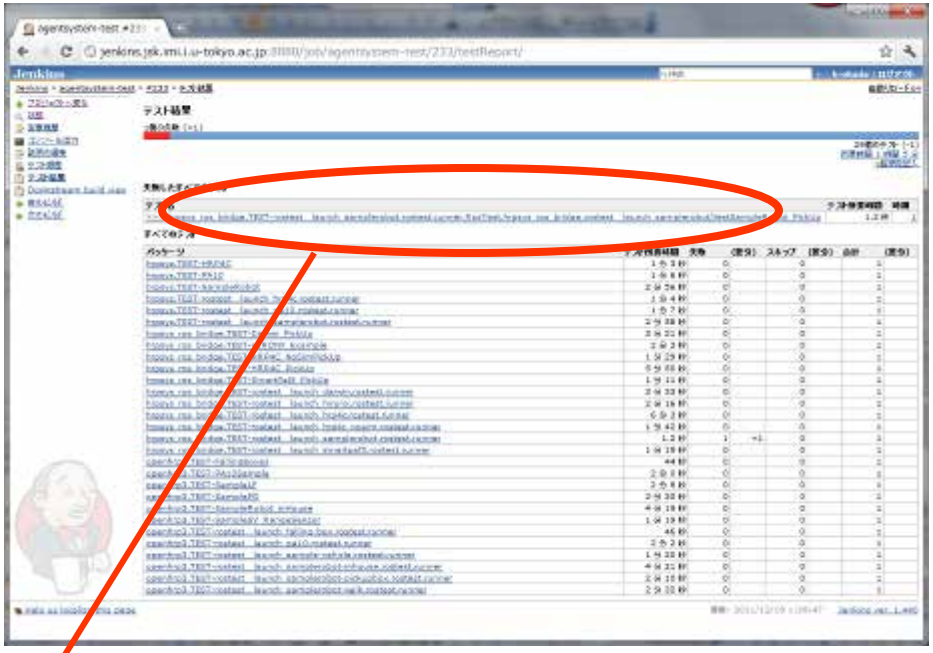


Test result of intelligent component(2)

- Report of sample testing code



Red indicates some of tests is fail, read means all tests are passed

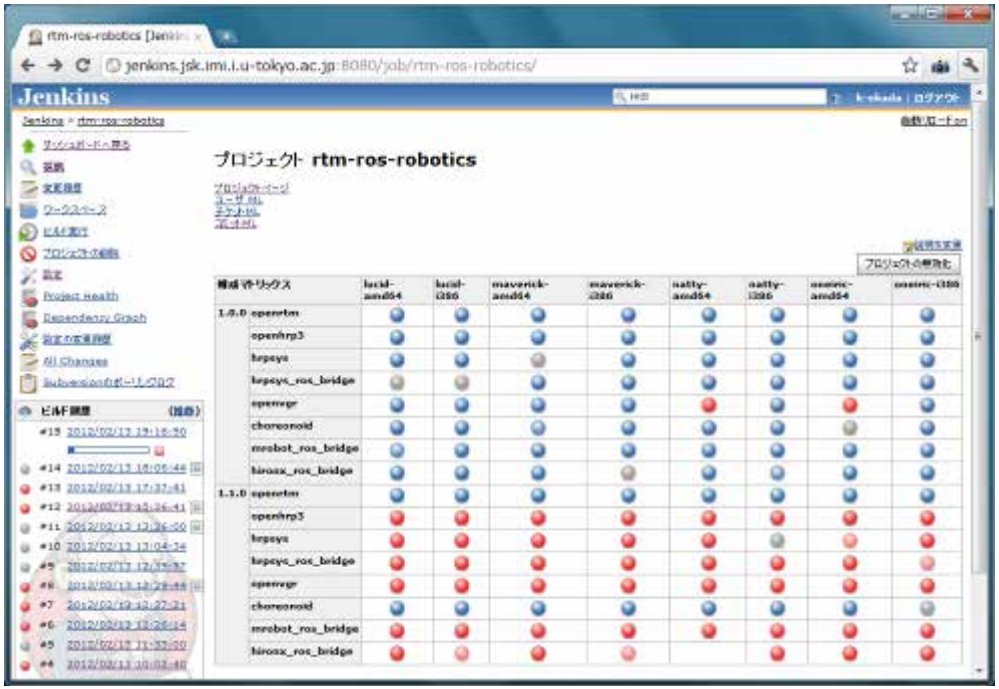


Web interface also provides the link to the failed test

http://jenkins.jsk.imi.i.u-tokyo.ac.jp:8080/job/agentsystem-test/

Verify on different version of CPU, OS Middleware

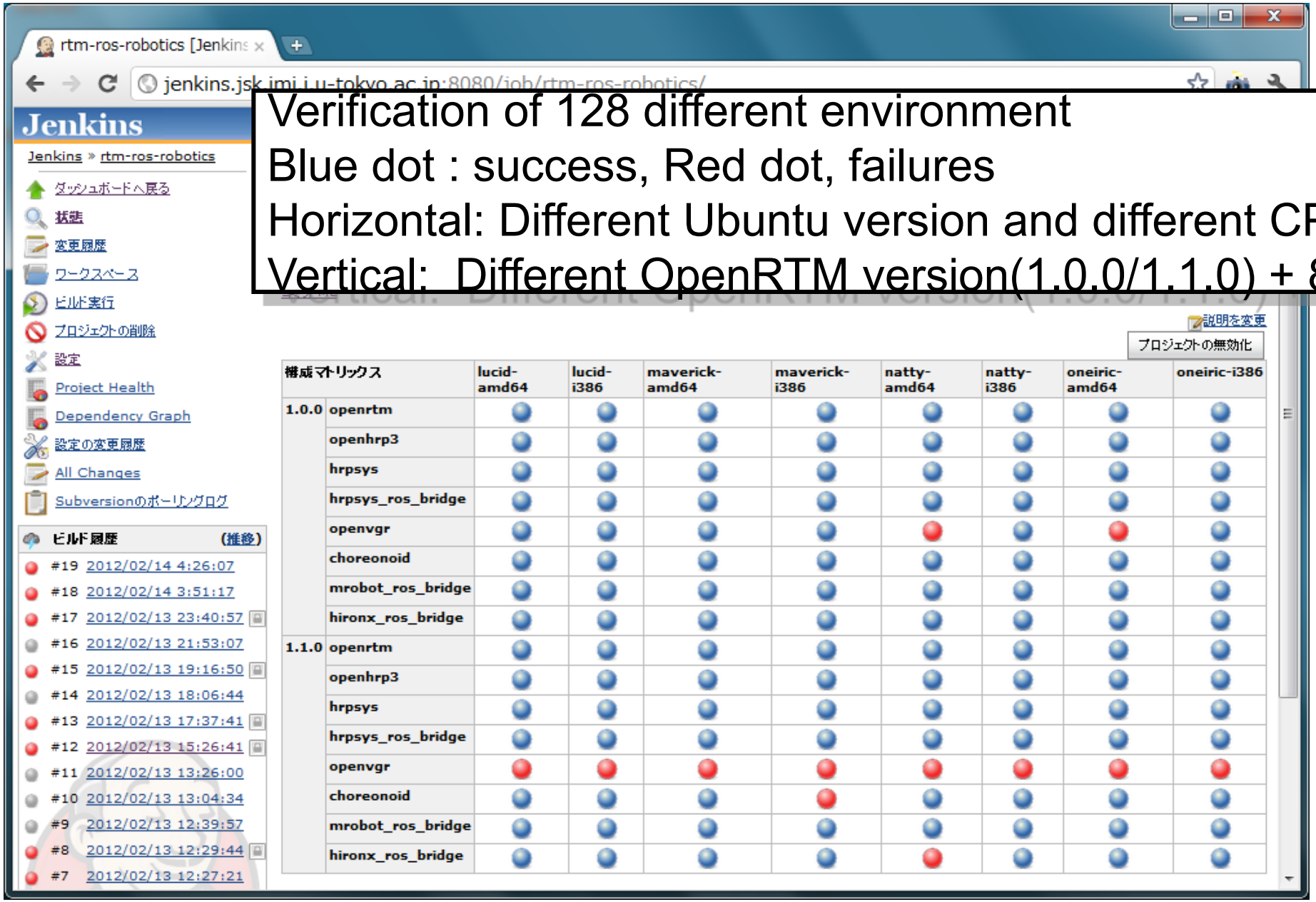
- Verify OS and middleware updates
- Combination of ordinal environment
  - CPU：32bit (i386), 64bit (amd64)
  - OS：Ubuntu 10.04, 10.10, 11.04, 11.10
  - OpenRTM: 1.0.0, 1.1.0
- Test each component for each of above 16 combinations
- Right figure shows verification for 8 components. As a total, we executes 128 verifications



horizontal：8 combinations (CPU x OS)

vertical： 8 components for two different OpenRTM versions

http://jenkins.jsk.imi.i.u-tokyo.ac.jp:8080/job/rtm-ros-robotics/


rtm-ros-robotics [Jenkins
jenkins.jsk.imi.i.u-tokyo.ac.jp:8080/job/rtm-ros-robotics/
Verification of 128 different environment
Blue dot : success, Red dot, failures
Horizontal: Different Ubuntu version and different CPU
Vertical: Different OpenRTM version(1.0.0/1.1.0) + 8
Jenkins
Jenkins » rtm-ros-robotics
ダッシュボードへ戻る
状態
変更履歴
ワークスペース
ビルド実行
プロジェクトの削除
設定
Project Health
Dependency Graph
設定の変更履歴
All Changes
Subversionのポーリングログ
ビルド履歴 (推移)
#19 2012/02/14 4:26:07
#18 2012/02/14 3:51:17
#17 2012/02/13 23:40:57
#16 2012/02/13 21:53:07
#15 2012/02/13 19:16:50
#14 2012/02/13 18:06:44
#13 2012/02/13 17:37:41
#12 2012/02/13 15:26:41
#11 2012/02/13 13:26:00
#10 2012/02/13 13:04:34
#9 2012/02/13 12:39:57
#8 2012/02/13 12:29:44
#7 2012/02/13 12:27:21
説明を変更
プロジェクトの無効化
構成マトリックス
lucid-amd64
lucid-i386
maverick-amd64
maverick-i386
natty-amd64
natty-i386
oneiric-amd64
oneiric-i386
1.0.0
openrtm
openhrp3
hrpsys
hrpsys_ros_bridge
openvgr
choreonoid
mrobot_ros_bridge
hironx_ros_bridge
1.1.0
openrtm
openhrp3
hrpsys
hrpsys_ros_bridge
openvgr
choreonoid
mrobot_ros_bridge
hironx_ros_bridge

Towards Practical RT Module Application

3rd step

Contribution to National Requirements

- **RTM Safety**
- **Disaster Robot equipped with RT modules**

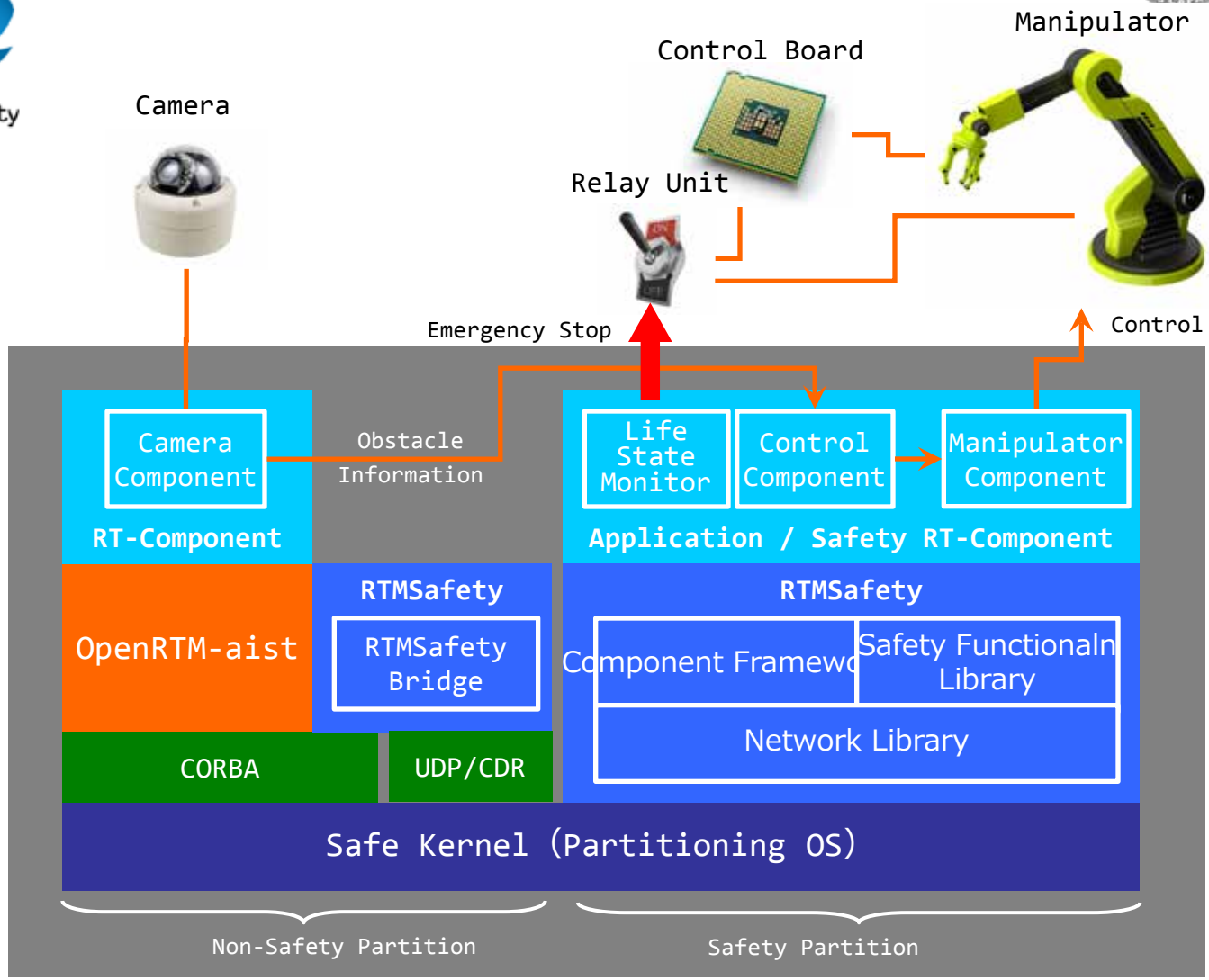
RTM Safety

SEC cooporation

RTM obtained IEC61508 Functional Safety Standard

RTMSafety

- **First in the word R middleware product equipped with Safety concept**
- **Obtained IEC61508 SIL3 Capable Certificate**
- Offer framework to adjust the load between Robot Component（RTC）and CPU load
- Equipped with the function of RTC monitor（Safety Function Library）
- Equipped with Light communication protocol following GIOP / CDR、cope with various types of network protocol（Network Protocol）
- Equipped with cooperation function with OpenRTM-aist（RTM Safety Bridge）



Nuclear Power Plant Robot equipped with RT modules

International Rescue Robot Center, Kyoto University, Tohoku UniversitySegway Japan）

※1：上記ロボットはすべてRTミドルウェア 上で動作
※2：NEDO「戦略的先端ロボット要素技術開発プロジェクト」で開発された成果の一部

- purpose：Verification of speck of Nuclear Power Plant robot, Disaster Robot
- Operator：　Kyoto Uni.、Int. Resque Center、Okayama Univ.、Nagoya Tech. Uni.
- Technical Advisor：Tohoku Uni.、Segway Japan、Tokyo Elec. Com. Univ.
- Cooperated by Tyugoku Electric Power Co.、NEC、Sick Co.
- Date：2012 Mar
- Place：　Shikoku Electric Power Com.Shimane Nuclear Power Plant
- Experiments：(1) Performance evaluation in real site
- (2) Sharing common experience with robot user
  (3) Evaluation of RT software modules
- **Merits of utilization of RTM：**
  - Exchangeability of hardware as well as software
    for exploratory realization of robot in such environment
    where target task cannot be clearly fixed in advanced.
    →Easy prototyping
  - Shortening of developing time ：Only 3～4 months
- Realized robot：“MATOI”（Kyoto Uni.）、“KOHGA3”（Kyoto Uni.）

Concluding Remarks

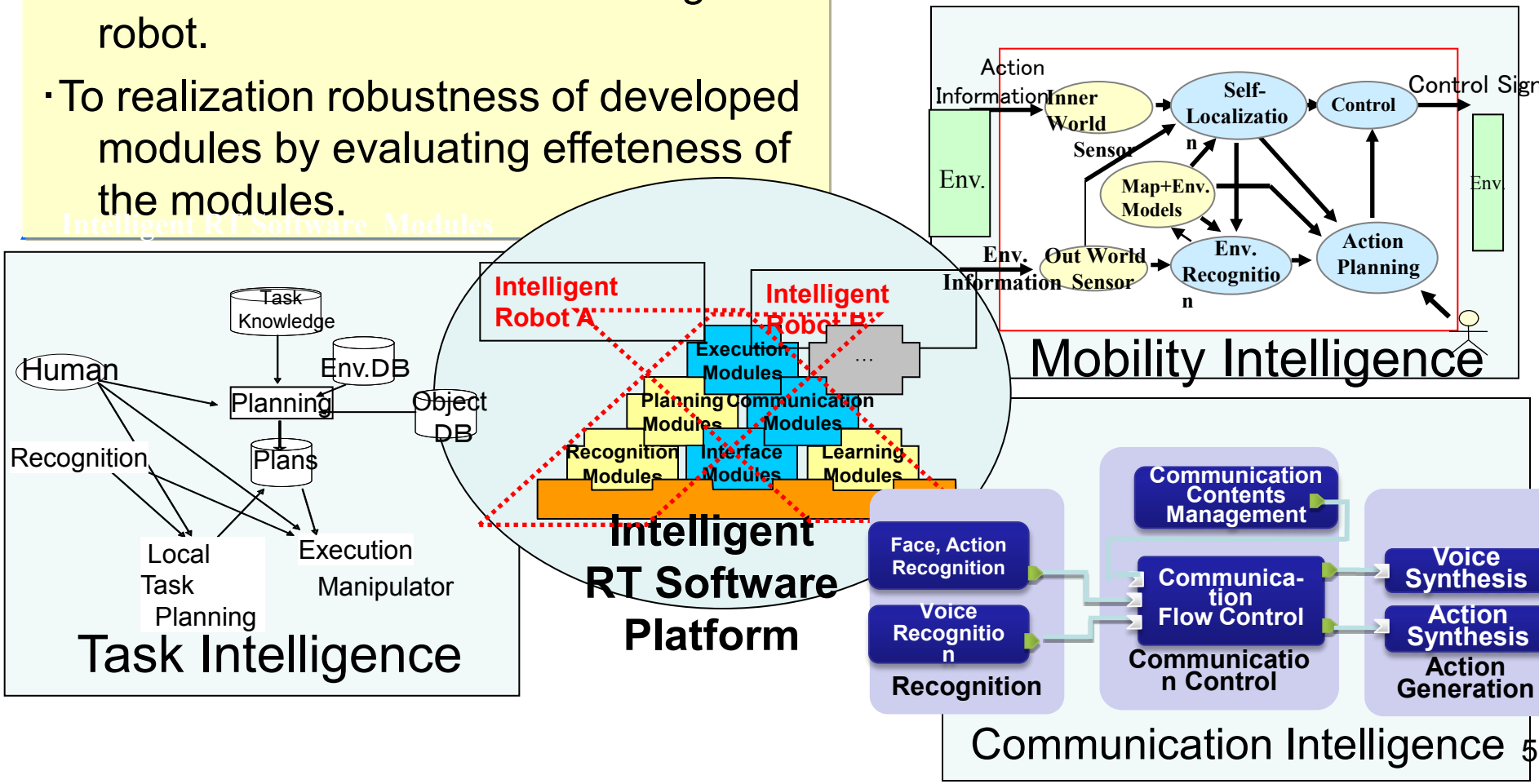
"Intelligent RT Software Project" Overview

Research Target

- To realize a software platform on which intelligent RT software can be integrated.
- To accumulate intelligent RT software modules to construct an intelligent robot.
- To realization robustness of developed modules by evaluating effeteness of the modules.

Period and Budget

Period
2007-2011 (5 year project)
Funding 67M$(Total)
19M$(2007), 15M$(2008), 13M$(2009),11M$(2010),10M$(2011)



Towards Practical Utilization of RT modules ～Steps and Efforts～

1st Step

- Accumulation of practical RT modules

2nd Step

- To offer software platform and RT modules

3rd step

- Contribution to National Requirements

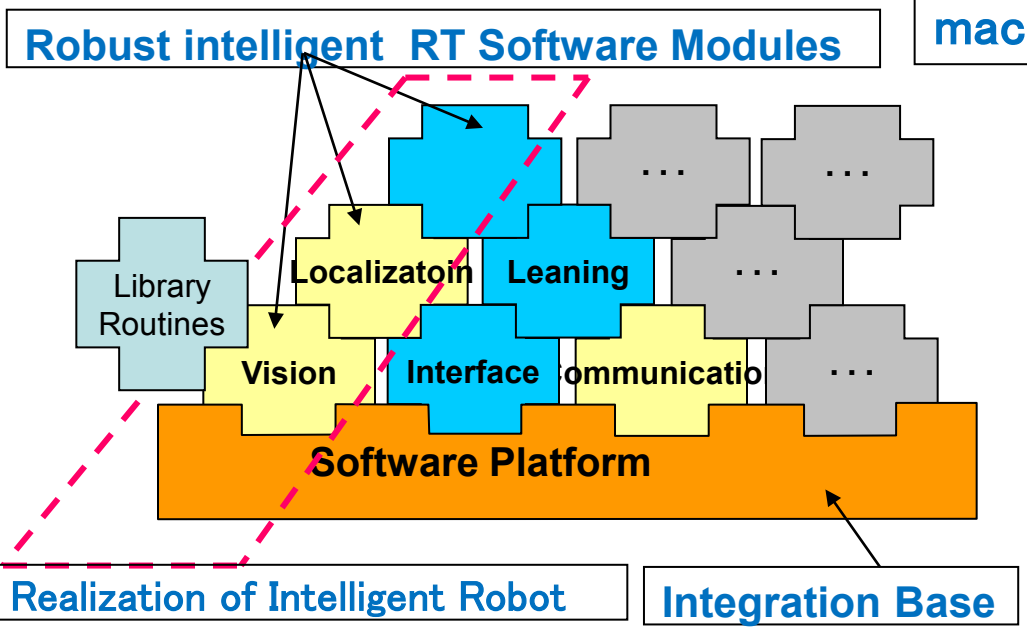
Intelligent RT Software Project

～Next Generation Robot Projects sponsored by NEDO: Ministry of Economy, Trade and Industry～

Project Targets

- Realization of “software platform” on which intelligent RT software modules can be integrated.
- Accumulation of “robust intelligent software modules” are required to realize an intelligent robot.

Practical Robot＝Individually functioning machine realized by social co-creation.



Robot + RT Services +Social Implementation mechanism

Rapid prototyping and rapid feedback are essential for the robot to be implemented in the society. Therefore, intelligent RT software modules offer basis to realize cost-effective robot with useful functions.