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.

Intelligent RT Software Modules

- Library Routines
- Vision
- Localizaton
- Leaning
- Interface
- Communication

Software Platform

Integration Base

Realization of 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

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modules should have common interface</td>
<td>Set common interface by establishing sub-WG</td>
</tr>
<tr>
<td>Modules should have integrity</td>
<td>Repeated integration evaluation by performing demonstration</td>
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<tr>
<td>Modules should be exchangeable</td>
<td>· Accepted research group focused on module utilization</td>
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<td></td>
<td>· Combined research groups to stimulate mutual utilization of modules</td>
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<tr>
<td></td>
<td>· Made full use of determined common interface</td>
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<tr>
<td>Modules should be easy to use</td>
<td>· Started open source software development</td>
</tr>
<tr>
<td></td>
<td>· Put stress on writing manuals and documents</td>
</tr>
<tr>
<td>Modules should be useful</td>
<td>· Evaluated developed modules by realizing an integrated robot</td>
</tr>
<tr>
<td>Modules should be complete to realize intelligent robot</td>
<td>· Wrote documents and manuals</td>
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<td>· Evaluates the completeness of software modules by demonstration during international exhibition</td>
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## Research Targets

### 4 Targets consisting of 8 Research Items

<table>
<thead>
<tr>
<th>I. Software Platform</th>
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<tbody>
<tr>
<td>① - 1 Development of intelligent robot software platform</td>
</tr>
<tr>
<td>① - 2 Improvement of reusability of software modules</td>
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</table>

<table>
<thead>
<tr>
<th>II. Intelligent software modules for manipulation</th>
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<tbody>
<tr>
<td>② Manipulation intelligence (Industrial robot)</td>
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<tr>
<td>③ Manipulation intelligence (Social • Life area)</td>
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</table>

<table>
<thead>
<tr>
<th>III. Intelligent software modules for navigation</th>
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<tbody>
<tr>
<td>④ Navigation Intelligence (Service robot)</td>
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<tr>
<td>⑤ Rapid navigation intelligence (Public space)</td>
</tr>
<tr>
<td>⑥ Navigation Intelligence (Social ans Life area)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>IV. Intelligent software for communication</th>
</tr>
</thead>
<tbody>
<tr>
<td>⑦ Communication Intelligence (Social life area)</td>
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</table>
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
① Robot Software Platform (AIST, NEC, SEC, Mayekawa, GR, TUAT)
①-2 Intelligent RT Software Modules Verification (AIST, Fujisoft)

Manipulation
② Manipulation Intelligence (Industrial Field) (Mitsubishi Electric, Kyoto Univ., IDEC)
③ Manipulation Intelligence (Social・Life related Field) (Toshiba, Tokyo Metropolitan Univ., Univ. Tokyo, Tohoku Univ., Rightechs, Robotics Space Design, PieCake, KYUTECH, Kyushu Univ., AIST, Yaskawa)

Mobility
④ Mobility 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)
⑤ High-speed Mobility Intelligence (Public Facility Field) (Keio Univ., JARI, AISIN, itransport, NECsoft, Hokkaido Univ.)
⑥ Mobility Intelligence (Social・Life related Field) (Segway Japan, Kyoto Univ., IRSI, Tohoku Univ., Kinki Univ., Shibaura I.T., Chiba I.T., NEC Soft, PUES)

Communication
⑦ Communication Intelligence (Social・Life related Field) (NEC, Osaka I.T., ATR, Omron, MHI, Eager)
<table>
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<tr>
<th>Year</th>
<th>Events</th>
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| 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 among 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

### OpenRT Platform

<table>
<thead>
<tr>
<th>Specification</th>
<th>Tools</th>
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<tbody>
<tr>
<td>Hardware</td>
<td>RTC Builder</td>
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<tr>
<td>RT Components</td>
<td>RTC Debugger</td>
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<tr>
<td>RT Systems</td>
<td>RT System Editor</td>
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<tr>
<td>Scenario Descriptions</td>
<td>Hardware Design Tool</td>
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<tr>
<td>Motion Pattern</td>
<td>RT Repository</td>
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<tr>
<td><strong>Middleware for modularization</strong></td>
<td>Simulator (OpenHRP3)</td>
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<tr>
<td><strong>OpenRTM-aist</strong></td>
<td>Motion Planner</td>
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<tr>
<td></td>
<td>Scenario Editor</td>
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<td></td>
<td>Real-Time verification tool</td>
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- RTC Builder
- RTC Debugger
- RT System Editor
- Hardware Design Tool
- RT Repository
- Simulator (OpenHRP3)
- Motion Planner
- Scenario Editor
- Real-Time verification tool
Robot System based on OpenRTM-aist-1.1

Network

Robot A
- Linux
- RTC
- RTM
- Solaris

Robot B
- Windows
- RTC
- RTM

Robot C
- TRON
- RTC
- ARTLinux

Application

Controller

Sensor
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.

RT Repository

- XML Database
  - Profile(XML)
    - RTC
    - RTS
    - Scenario (T.B.D)
    - H/W(T.B.D)

- File System
  - RTC Package
    - Source
    - Binary

RTC Builder

RTC Debugger

RT System Editor

Download Deployment

Register Update Search

Robot Systems

RT Portal (Web Site)
Intelligent RT Software Modules

Manipulation

Task Intelligence
Intelligent RT Software Modules

Navigation

Mobility Intelligence
Prototype 1

Prototype 1 With ABS cover

Prototype 1 With Metal cover
Intelligent RT Software Modules

Communication

Communication Intelligence
## Number of developed Modules

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<th>Year</th>
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<th>2010</th>
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<td>136</td>
<td>120</td>
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## Intellectual Properties

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<tr>
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<th>Research Presentation (Papers、Conference)</th>
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<td></td>
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<td>International</td>
<td>Domestic</td>
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<td>2007 ~ 2009</td>
<td>50 (0)</td>
<td>55</td>
<td>336</td>
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<tr>
<td>2011</td>
<td>13 (7)</td>
<td>53</td>
<td>172</td>
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<tr>
<td>2012</td>
<td>5 (0)</td>
<td>51</td>
<td>99</td>
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<tr>
<td>Total</td>
<td>6 8(7)</td>
<td>159</td>
<td>582</td>
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</table>

Total: 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

OpenVGR (6 modules)

Plan

graspPlugin for Choreonoid (2 modules)

Act

HiroNXInterface (2 modules)
User Can Select the best Module

Sense
- IEEE1394b Stereo camera
- Single USB camera
- Rangefinder SwissRanger
- Kinect

Recognition
- Common IF

Plan
- Grasp Plan
- Motion Plan
- Motion Control
- Cooperative Control

Scheduler

Act
- Dual-arm robot control
- Common IF

AIST
- Tokyo
- Toyohashi
- Tohoku
Video of each system

Video 1: Head stereo camera used dual arm robot for manipulation operation

Video 2: Hand camera used dual arm robot system for manipulation operation

Video 3: Dual arm robot and AGV connected system

Video 4: Dual arm robot by 5N force for coordination operation
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

**User interface**

Web browser based modules
Voice input based modules

**Object recognition**

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

**Robot Control**

Dual-arm control modules
Target: Japanese confections

Turuyahatiman
Tsuruya Yoshinobu
Fugetsudo
GODIVA

ANTÉNOR

PIERRE HERMÉ

Osaka Univ.
Cracker
Taneya
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

- User detection
- LRF data
- Laser range finder (LRF)
- HIRO head camera
- Camera image
- Object recognition
- Python script
- Robot control
- Motor command
- HIRO
- Dual-arm control
- Tablet PC
- Web order
- User interface
Setup of RT modules: Changed hardware

- User detection
  - Python script
  - Camera image

- Object recognition
  - Camera image

- HIRO head camera

- User interface
  - Voice order
  - Head set

- Robot control
  - Dual-arm control
  - Motor command

- HIRO
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

- Open source intelligent robot software modules

- Commercial robots are supported.

Accumulation of basic software modules for intelligent robots
Collection of enabling modules to select and combine freely
Collection of modules easy to use on available reliable robot
Intelligent Robot Software Suite

— ROBOSSA —

OpenRTC-aist

New function, technique

Intelligent Manipulation

New Service

New Hardware

Mobile Robot

New Sensors

New Tech.

Communication Robot

Communication

Mobile Robot

Research Platform

Industrial Robot Platform

Educational Robot Platform

NEDO-RTCs OSS RTCs etc.

Out:産省技術戦略マップ 2010
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

- Path Planning
- GUI
- Camera
- Ceiling Map
- Map
- RT System Editor
- OpenHRP3
Simulation
2) OpenRTM-ROS interoperability

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.

<table>
<thead>
<tr>
<th></th>
<th>OpenRTM</th>
<th>ROS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sponsors</td>
<td>MITI, MEXT, NEDO</td>
<td>WillowGarage</td>
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<tr>
<td>License</td>
<td>Open / Closed</td>
<td>Open License (BSD)</td>
</tr>
<tr>
<td>PI</td>
<td>AIST</td>
<td>Open Source Robotics Foundation</td>
</tr>
<tr>
<td>Design Principle</td>
<td>Component Strict framework for re-usability</td>
<td>Library Loose framework for development speed</td>
</tr>
<tr>
<td>Quality Control</td>
<td>OMG standard Reusability Center</td>
<td>None (voluntary based control)</td>
</tr>
</tbody>
</table>
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](http://www.ros.org/wiki/Metrics)

- **OpenRTM**
  - 45 repositories (include 15 companies = 33%)
  - 332 software modules
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

→ Building OpenRTM-ROS environment on ROS-tools
  - Connecting OpenRTM and modules developed in all over the world.
  - Efficient development and maintenance

Red indicates time to build tools, and green shows the research. Current PhD student spends 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:
RTM-ROS Interoperability Project

(A) Interoperability platform hardware

1. OpenRTM Mobile base + ROS Navigation
   - Support common interface designed in navigation SW group

2. OpenRTM Mobile Base + ROS Navigation + OpenRTM manipulator + OpenRAVE Planning
   - Common interface is designed in manipulation group
   - Using joint angle interface of SequencePlayer

Mobile robot beego
Yasukawa’s mobile unit FMK
3D block manipulation using OpenRAVE
Mobile manipulation robot
(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

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
Automatic testing and documentation of RT components

CI (jenkins tools)
- Download source codes (rosinstall)
  - Install libraries (rosdep)
  - Download and compile OpenRTM
  - Download and compile OpenHRP3
  - Compile iis_idl
  - Compile mrobot_ros_bridge
  - Download and compile hrpsys
  - Download and compile hrpsys_ros_bridge
- Test OpenHRP3
- Test hrpsys
- Test hrpsys_ros_bridge

Developer
- Commit source code into repository

Source code repository
(code.google.com/p/rtm-ros-robot)
- Polling
- Automated

Report
- Success or failure of compilation
- Sample motion test result
- Generate latest tag
- Generate sample motion video
- Generate sample motion document

Using real robot to check sample motion
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/
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

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Towards Practical RT Module Application

3rd step
Contribution to National Requirements

- RTM Safety
- Disaster Robot equipped with RT modules
RTM obtained IEC61508 Functional Safety Standard

- First in the world Robot 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 University, Segway Japan

- purpose: Verification of speck of Nuclear Power Plant robot, Disaster Robot
- Cooperated by Tyugoku Electric Power Co., NEC, Sick Co.
- Date: 2012 Mar
- Place: Shikoku Electric Power Co. 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 realize robustness of developed modules by evaluating effectiveness of the modules.

Period and Budget

Period
2007-2011 (5 year project)

Funding  67M$(Total)
19M$(2007), 15M$(2008),

Mobility Intelligence

Communication Intelligence

Intelligent RT Software Modules

Task Intelligence

Human
Recognition

Planning

Execution
Manipulator

Local
Task
Planning

Task Knowledge

Env.DATABASE

Object
DATABASE

Intelligent Robot Platform

Intelligent Robot A

Recognition Modules

Execution

Communication

Planning

Modules

Communication

Models

Recognition

Modules

Interface

Modules

Learning

Modules

Intelligent Robot B

...
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.